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UNITED STATES AIR FORCE

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AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AN ECONOMIC ANALYSIS OF A
GOVERNMENT SPONSORED, COMMERCIAL
CONVERTIBLE AIRCRAFT

Robert J. Morgan, Captain, USAF
Stanley L. Mead, Second Lieutenant, USAF

LSSR 21-77B

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REPORT DOCUMENTATION PAGE

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(14)

1. REPORT NUMBER: AFIT-LSSR-21-77B

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) AN ECONOMIC ANALYSIS OF A GOVERNMENT SPONSORED, COMMERCIAL CONVERTIBLE AIRCRAFT.

5. TYPE OF REPORT & PERIOD COVERED: (9) Master's Thesis

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10)
Robert J. Morgan, Captain, USAF
Stanley L. Mead, Second Lieutenant, USAF

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Graduate Education Division
School of Systems and Logistics
Air Force Institute of Technology, WPAFB OH

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS:
Department of Research and Administrative Management
AFIT/LSGR, WPAFB OH 45433

12. REPORT DATE: (11) Sep[redacted]77

13. NUMBER OF PAGES: 222 (12) 241 p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report):
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Ø12 25Ø

18. SUPPLEMENTARY NOTES:
APPROVED FOR PUBLIC RELEASE AFR 190-17.
JERRAL F. GUESS, CAPT, USAF
Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Air Carrier Traffic Forecast
Airlift
Civil Air Reserve Fleet
Military Aviation
Simulation Model

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):
Thesis Chairman: Joel B. Knowles, Captain, USAF

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The purpose of the study was to examine the time interval and associated discounted program costs of a government sponsored convertible aircraft. Through the use of a computer model, the researchers examined the relationship of deflated Gross National Product growth, historical air commerce trends, and simulated changes in the composition of the U.S. air carrier fleet resulting from the demand for air transportation. Further, the study examined the impact of wide-bodied aircraft lower hold cargo capability on attaining 100 wide-bodied cargo capable aircraft by 1990 as well as reimbursement by airlines for initial government sponsorship costs when convertible aircraft are transitioned to a freighter mode. The authors concluded air carriers' decisions on the type of aircraft selected to service air traffic growth could increase discounted government sponsorship costs by as much as \$202.6 million during the time period 1978 to 1990.

LSSR 21-77B

AN ECONOMIC ANALYSIS OF A GOVERNMENT SPONSORED, COMMERCIAL CONVERTIBLE AIRCRAFT

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degrees of Master of Science in Logistics Management

and Master of Science in Facilities Management

By

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September 1977

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MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
and
MASTER OF SCIENCE IN FACILITIES MANAGEMENT

DATE: 7 September 1977

Joel B. Knowles
COMMITTEE CHAIRMAN

ACKNOWLEDGMENTS

The assistance and advice of the authors' thesis advisor, Captain Joel B. Knowles, Assistant Professor of Logistics Management, is gratefully acknowledged. Appreciation is also extended to Mr. Richard Sowar for assistance in producing computer visual aides appearing throughout the thesis. Further, the researchers convey their sincere appreciation to Joyce A. Clark for her outstanding, conscientious, and virtually error free administrative support.

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CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

United States Air Force efforts to gain congressional approval to upgrade the capability of wide-bodied (WB) Civil Reserve Air Fleet (CRAF) aircraft have not been successful (74:152-53). Several studies have analyzed the major shortcomings of the strategic airlift system and resulted in both short and long term courses of action to resolve the strategic airlift deficit. The studies, however, do not attempt to analyze costs associated with government sponsorship of a commercial convertible aircraft in the context of an expanding U.S. economy. Specifically, initial and recurring costs of a convertible aircraft need to be analyzed in the context of the aircraft's future utility to a commercial airline and the economic feasibility of complete reimbursement to the government of initial sponsorship costs.

DEFINITION OF TERMS

The following definitions are provided to clarify and standardize terms frequently used throughout this study:

Air Carriers. A term used to refer to the combined operations of Certificated Route Air Carriers and Supplemental Air Carriers possessing fixed wing aircraft only.

Certificated Route Air Carrier (CRAC).

> An air carrier holding a certificate of public convenience and necessity issued by the CAB authorizing the performance of scheduled service over specified routes. Certain nonscheduled, or charter operations may also be conducted by these carriers [13:95].

Civil Reserve Air Fleet (CRAF). The CRAF is comprised of U.S. registered civil transport aircraft operated by Certificated Route Air Carriers and Supplemental Air Carriers, as outlined in Appendix A. The number and type of aircraft required to support Joint Chiefs of Staff (JCS) approved contingency plans are determined by Military Airlift Command (MAC) and forwarded to the Director, Office of Emergency Transportation (OET), Department of Transportation (DOT), who in turn allocates civil aircraft to the CRAF by FAA registration number. Allocation is made to one of the four CRAF segments (see Appendix B) depending on the aircraft's operating characteristics. CRAF participants must be capable of responding with committed aircraft and aircrews as outlined in contracts with MAC. Activation of the CRAF can occur in any one of three stages ranging from limited expansion of airlift capability committed to the Commander, MAC (Stage I) to emergency situations requiring additional airlift capability to meet major contingency airlift requirements

(Stage II) and requirements resulting from a state of national emergency declared by the President (Stage III). Response time ranges from 24 hours for Stages I and II to 48 hours for Stage III (71:2—1-2—4).

Convertible Aircraft. "An aircraft built with reinforced flooring, removable seats, and movable bulkheads, so it can be transformed from passenger to cargo configuration [61:121]." The cargo capability of a convertible aircraft is dependent on structural provisions selected by the commercial airline. Specifically, design options include varying degrees of floor reinforcement, removal of passenger equipment, cargo handling equipment such as a powered loading system, and optional nose and side entrance doors (60:25-38).

Express (Air).

> Property transported by air under published air express tariffs filed with the Civil Aeronautics Board. The transportation by air of express is conducted on the basis of agreements between the Railway Express Agency and the air carriers [13:95].

Freight. "Property other than express and passenger baggage transported by air [13:96]."

Freighter. "An aircraft suited only to freight (or cargo), rather than passengers. Also known as regular or pure freighter [61:123]."

Gross National Product (GNP).

> The market value of final goods and services produced by the labor and property supplied by residents of the United States, before deduction of allowances for the consumption

of fixed capital goods. It is a comprehensive measure of aggregate economic output [18:4].

National Strategic Airlift Resource (NSAR). The combined capability of the International Civil Reserve Air Fleet and the strategic airlift force of the Military Airlift Command (27:4).

Outsized Cargo. The military term for cargo which exceeds the loading capability of the C-141 cargo aircraft. "Any item of cargo which exceeds 810" x 117" in any dimension [60:8]."

Oversize Cargo. Cargo which cannot be placed on a single pallet either due to its weight or dimensions. Cargo classified as oversize for a commercial aircraft is not necessarily oversize for a military aircraft. The term is further amplified in the context of military and civilian aircraft as follows:

a. Military Aircraft. Oversize cargo for military aircraft is that cargo wherein weight exceeds 10,000 lbs. (the stressed weight limit for 463L pallet) or any dimension which exceeds 104" x 84" x 48". Cargo requires special loading on C-130/C-141 or larger aircraft [60:8].

b. Civilian Aircraft. Oversize cargo for civilian aircraft is that cargo wherein weight exceeds 10,000 lbs. (the stressed weight limit for 463L pallets) or any dimension which exceeds 104" x 84" x perpendicular heights (at opposing ends of the 104 dimension) of 48" and 58" which are increased to a maximum of 77" subject to the curvature of the cargo envelope of the applicable sideloading aircraft. Note: Since there are a number of different models of civilian aircraft, there is a variety of shapes and sizes of cargo envelopes. DETAILED planning must be accomplished in accordance with the cargo loading specifications for the particular model aircraft [60:8-9].

Revenue Passenger Load Factor (RPLF).

The percent that revenue passenger-miles are of available seat-miles in revenue passenger services, representing the proportion of aircraft seating capacity that is actually sold and utilized [13:98].

Revenue Passenger-Mile (RPM).

One revenue passenger transported one mile in revenue service. Revenue passenger-miles are computed by the summation of the products of the revenue aircraft miles flown on each inter-airport leg multiplied by the number of revenue passengers carried on that hop [13:98].

Supplemental Air Carrier. A classification of air carriers holding certificates of public convenience and necessity issued by the CAB, authorizing them to perform passenger and cargo charter services supplementing the scheduled service of the certificated route air carriers (7:139).

Ton-Mile.

One short ton (2,000 pounds) transported one statute mile (5,280 feet): ton-miles are computed by multiplying the aircraft miles flown on each inter-airport hop by the number of tons carried on that hop [13:98].

U.S. Civil Air Carrier Fleet. A generic term used to refer to total aircraft operated by all aircraft operators certificated by the Federal Aviation Administration (FAA) for the transportation by air of persons, property, and mail. The fleet is comprised of five types of air carriers: Certificated Route Air Carriers, supplemental air carriers, commercial operators, air taxi operators, and travel clubs (23:58,139).

Wide-bodied (WB) Aircraft. An aircraft of sufficient size to permit aircraft seating based on configurations which the Civil Aeronautics Board (CAB) uses as a standard for rate-making purposes. For three engine wide-bodied jets the standard is 9 abreast coach seating. The B-747 standard is 10 abreast (1:10).

BACKGROUND

The National Strategic Airlift Resource role during wartime or emergency military operations is to provide adequate and timely strategic airlift of augmentation forces, weapons, and resupply to the theater of operations (27:6). At this time, the importance of strategic airlift is unchallenged and increasing as a result of withdrawing U.S. military forces from foreign bases (38:16). Further cause for concern is the numerical superiority of the Warsaw Pact ground forces in Eastern Europe over North Atlantic Treaty Organization forces. Following a trip to Europe, Senators Nunn and Bartlett reported to the Congress on January 24, 1977 that "Soviet forces deployed in Eastern Europe now possess the ability to launch a potentially devastating conventional attack on Central Europe with little warning [6:2]." There is also a growing realization that effectively countering overt hostile military action through neutralizing a situation with conventional weapons is prerequisite to averting a nuclear confrontation and the devastation that follows . The National Strategic Airlift Resource

forms a vital part of our military strategy in providing effective deterrence (19:28). The key term "deterrence" is defined as the "prevention from action by fear of the consequence [59:18]." General Paul K. Carlton, Commander of MAC stated:

> . . . Deterrence is a condition that exists in your adversary's state of mind, not your own. The only way to achieve that deterrence effectively is to clearly establish the fact that you're ready for combat if need be . . . [6:11].

Deterrence, strategic mobility, and a viable strategic airlift system are inseparable concepts. Lieutenant General Fred Kornet, Jr., U.S. Army DCS/Logistics, highlighted the significance of the relationship:

> Today, in an era of global politics, rapid and sophisticated communication and transportation capabilities and the ever-present threat of global conflict, mobility has taken on dimensions of staggering proportions . . . . In a major contingency Army forces represent more than 90 percent of unit equipment deployment requirements and require more than 60 percent of the total supplies shipped in support of U.S. forces. Our ground forces are our major deterrent to conventional aggression. However, they would be of little value as a deterrent force without the capability to rapidly move them into a potential area of conflict [38:15-16].

The rapid deployment of the Army's heavy firepower units is one of the most important tasks of the National Strategic Airlift Resource; however, it is in this area that the capability to transport outsize and oversize cargo is severely limited (27:6). The situation was described by General Carlton as follows:

> But cargo is a different matter: A full-scale crisis that called for Civil Reserve Air Fleet mobilization would demand 100 percent of the airlines' present cargo capacity--in other

> words, all the air cargo and air freight capacity in the nation--and that still wouldn't be enough, especially in the area of oversize cargo [21:29].

In a study recently completed by the Logistics Management Institute under the sponsorship of the Office of the Assistant Secretary of Defense (Installations and Logistics), General Howell M. Estes, Jr., USAF retired, concluded:

> The combined capability of the strategic airlift force of MAC and the international CRAF is substantially less than that which is required to execute national war contingency plans, and the readiness posture of MAC has now reached, or is rapidly approaching, a level from which an immediate surge to and maintenance of specified wartime operating rates cannot be expected [27:25].

This observation regarding strategic airlift is not dissimilar to the one that prompted the late President Harry S. Truman to sign Executive Order 10219 in February 1951, creating the CRAF program (66:50). Subsequent investigations in the early 1960s continued to highlight strategic airlift deficits. As a result of recognizing that neither the military nor civilian sector had a viable airlift capability, congressional action prompted the procurement of the present day C-141 fleet. Throughout the 1960s congressional subcommittees continually pointed to cargo deficiencies in the National Strategic Airlift Resource (66:34-38).

As a blend of approximately 350 military and 230 CRAF long-range international aircraft (see Appendix B), the National Strategic Airlift Resource can fulfill all current passenger deployment

requirements during wartime; however, even though the CRAF provides 41% of the total cargo airlift capability, it "accounts for only 27% of the oversize lift now available from the total National Resource and none of the outsize [27:21]." Recommendations for resolving the shortfall include the following:

1. In May 1973, Mitchell (39) recommended partial government financing of the additional cost attributable to a convertible aircraft as opposed to a straight passenger configuration. His recommendation included a provision whereby an airline would reimburse the government up to the initial amount financed whenever the aircraft is used to satisfy strictly commercial cargo requirements of the airline (39:62).

2. In May 1973, Pugh (60) concluded:

> . . . The Department of Defense should provide commercial air carriers with incentives to procure additional B-747C aircraft. The incentives should represent a combination of three forms:
>
> a. A direct government subsidy to the air carriers that would allow procurement of convertible rather than passenger aircraft.
>
> b. A direct payment to air carriers to convert A and B model 747 aircraft to the convertible configuration.
>
> c. A guarantee for CRAF participants of an annual share of the MAC airlift business [60:63].

3. In April 1976, Estes (27 & 28), completed a two volume study focused on the National Strategic Airlift Resource dilemma. He

concluded the only long term alternative to eliminating the strategic airlift deficit is government sponsorship of a fleet of long range cargo capable, commercially owned and operated aircraft of sufficient size and quantity to resolve the shortfall (28:27).

The studies accomplished on the subject of the National Strategic Airlift Resource provide a useful framework on which to build an understanding of the strategic airlift system. However, the studies were primarily oriented at identifying and analyzing major shortcomings of the strategic airlift system. They did not attempt an economic or cost sensitivity analysis of net projected costs of a government sponsored fleet of convertible type aircraft to meet long term requirements. The studies did stress, however, the need for examining the fiscal feasibility of a government sponsored fleet of internationally capable, convertible aircraft taking into consideration the uncertainty of long term air commerce trends.

JUSTIFICATION

The current capability of the United States National Strategic Airlift Resource is insufficient to meet mobilization requirements reflected in wartime planning documents (27:6). As a nation committed to a military policy of strategic mobility, General Carlton stated:

> Timely transportation of essential cargo and personnel to the right place in the right combinations is one of the most critical management problems faced by Department of Defense planners [20:6].

One alternative to overcoming the critical management problem of resolving the serious strategic airlift shortfall is expanding the capability of the CRAF (27:21). Expansion of the CRAF capability can be accomplished in two ways. First, existing CRAF WB aircraft can be modified to enhance their capability to transport a greater percentage of oversized cargo to meet emergency military requirements. Second, new aircraft necessary to meet commercial growth requirements can be procured in a convertible configuration to maximize the CRAF capability to transport oversize cargo during emergency situations. Each alternative poses inherent problems for commercial airlines and the U.S. government. The most apparent problem is funding the initial cost of either alternative.

The need for a WB aircraft configured to enable loading of oversize combat equipment was highlighted in Estes' 1976 study where he concluded:

> In an emergency, CRAF wide body passenger aircraft could transport bulk cargo in the belly compartment and, through removal of seats and placing of plywood shoring on the main deck, could carry some additional light bulk cargo in the cabin. The limitations in cabin loading, in addition to those pertinent to floor strength, are the passenger door dimensions and the lack of cargo tie down provisions. These limitations are so severe that, in their present configuration, the CRAF wide body passenger aircraft are pratically [sic] useless in an emergency for other

than passenger carriage. CRAF has total passenger carriage capability which is far in excess of the passenger movement requirements of current war contingency plans and hence, these aircraft are not essential to that purpose [28:22].

In the case of the B-747 WB passenger aircraft, convertible options can be incorporated through one of three basic modifications offered by the manufacturer to enhance the aircraft's cargo carrying capability (60:37). Attempts by the Air Force to obtain funds to modify existing CRAF B-747 aircraft have centered on Boeing Company's Configuration M-4 ("mini-mod" or minimal floor reinforcement with nose cargo door) and Configuration IIB ("full mod" or maximum floor reinforcement with a side cargo door) (28:24). Operating empty weight (OEW) penalties while in the passenger mode for the two configurations were estimated by Boeing to be 2,600 and 9,700 pounds, respectively (4:6,9). The main reason for the modification was to improve the capability of existing CRAF WB aircraft to handle a greater percentage of oversized cargo during emergency situations. The following describes the significant features of each modification:

Modification 1 [Configuration M-4]. Minimum reinforcement of floor beams. Minimum removal of passenger equipment. Installation of provision for roller trays, tie-down, and other cargo handling equipment as in the 747-200C except without the powered loading system. This option permits the loading of 8' wide x 8' high containers on one side and 88" wide pallets on the other [39:63].

Modification 3 [Configuration IIB]. Maximum floor reinforcement commensurate with the design strength of the [B-747]-100 airplane. Cargo handling provisions and

fuselage frame notching as required to load 8' wide by 8' high cargo side by side. Power loading system. Minimum passenger equipment removal [39:63].

In 1975 the Air Force initiated action to modify 110 B-747 aircraft at a total program cost of $793 million. The program cost spanned a fifteen year period and was described as follows:

> It includes the installation of a nose visor cargo door and/or large side loading door (depending upon the model of aircraft involved), the strengthening of the upper cargo deck, and the installation of a cargo floor weight distribution system. In addition, the Air Force proposes to pay the airlines for loss of revenue during the period for committing the modified aircraft to the Department of Defense's CRAF program for the remainder of their service life, for higher operating costs because of the additional increase to the basic weight of the aircraft resulting from the modification, for expenses incurred for the additional maintenance required, for storage of conversion kits, and for making the aircraft available during contingencies [72:247].

The program was rejected by Congress for fiscal year 1975; however, the Air Force budgeted $22 million to initiate the program in fiscal year 1976. The request was subsequently turned down by Congress (72:248). In March 1976, Lieutenant General Alton D. Slay, Deputy Chief of Staff, Research and Development, appeared before the Senate subcommittee of the Committee on Appropriations to support the fiscal year 1977 budget request for Air Force procurement contracts. The fiscal year 1977 budget proposals indicated a total CRAF modification program cost of $492.4 million projected over a five year period to include 81 B-747 aircraft (12:24). The budget included a fiscal year 1977 request for $29.3 million to support the modification

program and indicated a fiscal year 1978 budget requirement of $96.1 million.

In response to several questions posed by Senator John L. McClellan, Chairman of the subcommittee, Lieutenant General Slay testified that the CRAF capability to transport oversized equipment would be increased significantly depending on the extent to which a B-747 was modified. A "mini-mod" consisting of a nose door and partially strengthened floor would enable a B-747 to load and transport "60% of the Army's oversize combat equipment--but no outsize [74:328]." A full modification (full-mod) would involve a large side cargo door and cargo floor similar to the B-747 commercial freighter. The modification would allow loading "80 percent of oversize combat equipment--but, again no outsize [74:328]." The following testimony by General Slay highlighted the need for additional cargo capability equated in terms of approximately 100 B-747 convertible aircraft:

> These aircraft would share the total airlift workload with the military airlift aircraft. If we achieve eventually a mix of mini-mods and full mods equivalent in capability to about 100 B-747s, then these civil aircraft, together with the outsize-capable C-5 and the stretched C-141--both operating at a 12.5 hour daily utilization rate--would provide the total capability necessary to meet the estimated shortfall in the early 1980s. This is our ultimate goal of the Airlift Enhancement Program [74:328].

The fiscal year 1977 budget request for an initial $29.3 million to modify six B-747 aircraft was subsequently disapproved. The House of Representatives Committee on Appropriations'

recommendation for terminating the CRAF modification program emphasized the various strategic airlift enhancement programs the Air Force had underway. The programs cited were the C-5A wing modification costing an estimated $1.1 billion, the C-141 stretch modification costing an estimated $681 million, the advanced medium Short Take Off and Landing (STOL) transport aircraft costing $4.5 billion, and the Advanced Tanker/Cargo Aircraft (ATCA) program estimated at $3 billion for 41 tanker/cargo (DC-10 or B-747) aircraft (60:152-153). The committee also recommended the Air Force original budget request for $37.2 million in advance procurement funds for the ATCA be reduced to $11.7 million. Justification for the budget cut was outlined as follows:

> While the Committee recognizes the need for tanker/cargo aircraft to refuel our strategic airlift capability, it is not convinced of the urgency of this program or that the Air Force has adequately studied all available cost-effectiveness alternatives [73:152].

Following the inauguration of President Carter in 1977, his administration reinstated a $30 million fiscal year Air Force request for initial funding of the CRAF modification program previously deleted by the Ford administration. The House committee, however, voted to delete the funds from the fiscal year 1978 budget (37:32).

A survey of studies conducted by Mitchell (14), Pugh (18), and Estes (12) centering on possible alternatives to resolve the strategic airlift deficit reveal the significant impact of producing a

convertible aircraft instead of modifying existing aircraft. Pugh's comprehensive study of the potential use of a B-747C convertible as a CRAF resource indicated a $1.6 million difference in costs between a modified B-747 (full modification) and a B-747C with an identical capability (60:38). Pugh's estimate made in 1973 dollars indicates 81 convertible aircraft produced on the production line would cost at least approximately $129 million less than the same quantity of aircraft modified after being placed in service.

The relative increase in strategic airlift capability through the introduction of new convertible aircraft into the CRAF can be achieved only through new aircraft orders by commercial airlines. Current forecasts by the Air Transport Association of America (ATA), indicate a traffic growth of 5 percent annually. The growth pattern translated into capital requirements to replace existing aircraft and compensate for the growth pattern equates to commercial airlines spending a cumulative $26 billion by the year 1985 for new aircraft (1:2-6). The ATA growth projection is conservative compared to the U.S. DOT-FAA forecast of at least 6 percent (41:11).

Assuming the conservative ATA forecast depicts the long term growth of commercial airlines, the strategic airlift deficit could be eliminated through government sponsorship of the initial cost difference between a passenger and convertible type aircraft. Further, a synthesis of civilian and military requirements would be achieved if

the air cargo market was sufficient to induce the commercial airlines to operate the convertible aircraft in the freighter mode. Mitchell proposed the following idea:

> . . . for every time that the airline used the aircraft in its cargo configuration, it would pay a set fee to the Government until the amount that the Government has spent to acquire the convertible aircraft has been paid back. If the airline never used the aircraft in the cargo configuration, the Government would still own its portion and if the aircraft was resold, the Government would receive its proportionate share [39:62].

This research undertook an examination of the interrelationship of long term air commerce growth and net projected costs of a government sponsored convertible aircraft to satisfy the national strategic airlift shortfall.

DELIMITATION

Scope

The scope of this research was limited to:

1. Development of a computer model to conduct a cost sensitivity analysis of a government sponsored CRAF WB cargo capable aircraft as outlined in recommendations contained in the following studies:

a. The National Strategic Airlift Dilemma, Volumes I and II (27 and 28).

b. An Evaluation of the Civil Reserve Air Fleet (CRAF) and Its Ability to Support the Strategic Airlift Requirements in the Mid-70s (39).

c. The Boeing 747C's Potential as a Civil Reserve Air Fleet Resource (60).

2. Employment of estimating methods for air freight volume used by Rand Corporation and published in Rand Report No. R-988-NSF, entitled, Methods for Estimating the Volume and Energy Demand of Freight Transport.

3. The assumption that narrow bodied (NB) aircraft were purchased to replace worn out NB aircraft. In essence, the assumption discounted the possibility that NB aircraft wear out would impact significantly on WB aircraft procurement.

4. Validation of the computer model by comparison with aviation market forecasts available from the Air Transport Association of America and Federal Aviation Administration.

Objectives

The objectives of the research were to:

1. Construct a computer model to determine the level of GNP growth required to support a demand for a minimum of 100 WB convertible aircraft. The B-747 aircraft manufactured by the Boeing Company was used as the standard long range WB aircraft for all calculations.

2. Determine the net total government sponsorship costs for the time period 1978-1990 based on airline reimbursement when convertible aircraft are used in a cargo configuration.

RESEARCH QUESTION

Can the National Strategic Airlift Resource deficit currently estimated at 100 cargo capable B-747 aircraft be achieved economically through government sponsorship of a WB convertible aircraft?

1. Over what time interval would 100 cargo capable B-747s be phased into the air carrier fleet as a result of varying levels of national economic growth?

2. At various levels of economic growth, how long would it take before the freighter mode of a convertible aircraft would be used by commercial air carriers?

3. What would be the total net cost of such a program taking into consideration reimbursements by the air carriers?

CHAPTER II

METHODOLOGY

The United States is faced with an increasing need to maximize the utility of its physical resources. As U.S. military forces are withdrawn from overseas, the relative importance of maintaining the integrity of the National Strategic Airlift Resource becomes more acute. In the words of General Carlton:

> A more effective program must be developed now, to eliminate the deficit in cargo airlift capability. I repeat, this is a national problem. Its solution should involve working hand-in-glove with our Nation's resourceful and highly innovative industrial community. We must decide upon, and work toward, a common objective which will benefit civilian society and Defense alike [21:28-29].

The methodology described in this chapter provides a framework through which the recommendation for a government sponsored aircraft advanced by earlier studies was examined in the context of economic considerations and historical air commerce data. Specifically, through the use of an estimating technique used successfully by Rand Corporation in 1972 to estimate freight volume and a computer program developed by the researchers, a cost sensitivity analysis was undertaken to examine the pay back period of government sponsorship costs at various levels of U.S. economic growth.

DESCRIPTION OF THE POPULATION

During the course of the study, the United States Air Carrier Fleet encompassed five primary groups of air carriers as depicted in Figure 1. Certificated Route Air Carriers (CRAC) and Supplemental Air Carriers comprised 84 percent of the total fleet of aircraft (23:51). The remaining three groups of air carriers (Commercial Operators, Air Taxi Operators, and Travel Clubs) were not participants in the CRAF and did not possess WB aircraft. Consequently, the population for this thesis was limited to the CRAC and Supplemental Air Carriers outlined in Appendix A.

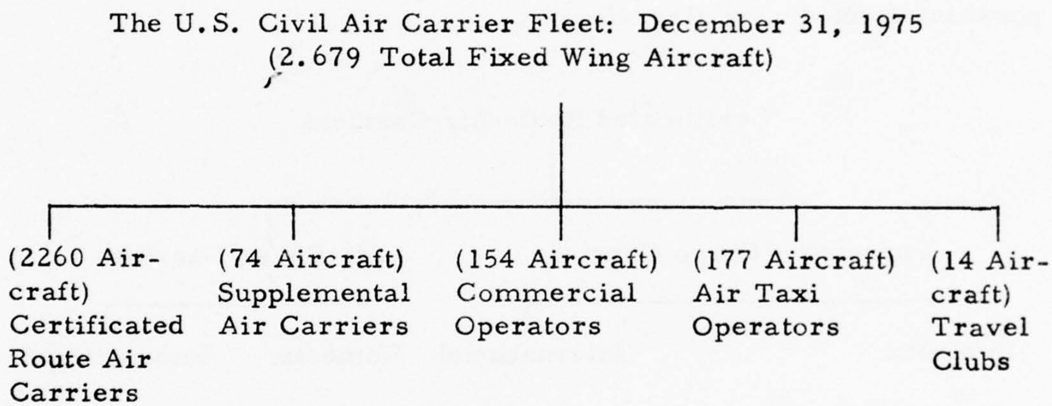
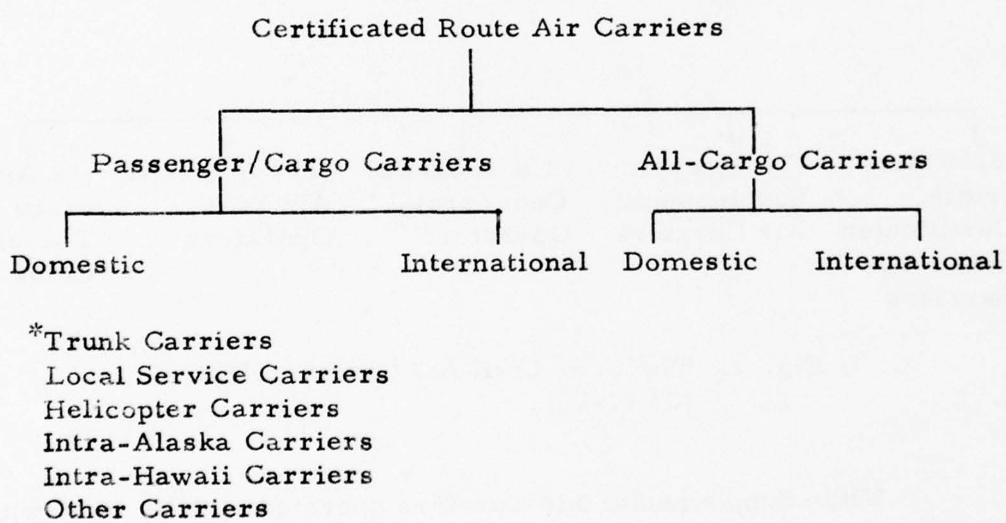


Fig. 1. The U.S. Civil Air Carrier Fleet (23:51-70)

While Supplemental Air Carriers operated strictly fixed wing aircraft and represented a distinct air carrier class, CRAC were subdivided into two groups representing passenger/cargo and all-cargo carriers. Both groups were further defined in terms of domestic and

international/territorial operations. Figure 2 depicts composition of the Certificated Route Air Carriers Group in relation to passenger/cargo and all-cargo carriers. Helicopter air carriers were included in Figure 2 to provide a complete presentation of the total CRAC group. As of 31 December 1975, there were three helicopter air carriers which accounted for less than 0.005 percent of all revenue passenger miles (PRM) flown. Further, two ceased operations completely in the latter part of 1976 (13:1, 9, 88). Therefore, all data collected was interpreted as generated by fixed wing aircraft activity. Hence, the general term "air carriers" will be used hereafter to refer to the combined operation of CRAC and Supplemental air carriers possessing fixed wing aircraft only.



*All trunk carriers except United Airlines have both domestic and international/territorial operating certificates.

Fig. 2. Certificated Route Air Carriers (23:71)

The overall capability of the air carriers to meet the demand for air transport services is dependent on the size and type of aircraft possessed. Table I outlines the types and quantities of aircraft in operation by the air carriers at the close of 1975.

Table I
Aircraft in Operation by Certificated Route and Supplemental Air Carriers: December 31, 1975
(23:61-65)

Aircraft Type	Quantity	
	Certificated Route Air Carriers	Supplemental Air Carriers
*B-747	97	1
*DC-10	121	4
*L-1011	75	0
DC-8	177	29
B-707	264	0
B-720	23	3
L-188	16	27
B-727	765	4
B-737	133	0
DC-9	337	4
BAC-111	30	0
CV-580/600	88	0
F-27/F-227	39	0
Other Two Engine Turboprop	50	0
Piston	45	2
Total	2260	74

*Wide-bodied (WB) aircraft.

DATA REQUIREMENTS

Prior to 1950, the economy exhibited several severe fluctuations. Therefore, the time period selected as the basis for this thesis was 1950 through 1976. Use of the post-World War II period reduced the marked influence wartime activity had on all modes of transportation and the U.S. economy in general (68:5-9). The overall objective of the Rand report titled, "Methods for Estimating the Volume and Energy Demand of Freight Transport," was "to develop better methods for estimating future demands for all forms of energy in the United States [68:iii]." The methodology used to develop future estimates of total U.S. domestic energy demand embraced a comprehensive analysis of all forms of freight transport. Specifically, predictions of estimated freight transportation requirements were translated into future energy requirements. A minor modification of the approach used in the Rand study permitted the translation of projected transportation requirements into estimated demand for new aircraft as opposed to estimated demand for energy.

A computer model was developed to facilitate processing of historical and projected data. Specific requirements for data relevant to U.S. economic growth, air carrier operations, and aircraft production costs were collected from the following sources:

1. Passenger, mail, and air cargo movements by air carriers, in terms of passenger revenue miles, cargo ton-miles, and

load factors for both domestic and international operations were compiled from various editions of statistical handbooks published by the FAA. The handbooks summarize in detail numerous tables of data consolidated from data collected by the Bureau of Accounts and Statistics, Civil Aeronautics Board (CAB). Data for 1976 was obtained from the CAB Air Carrier Traffic Statistics. Appendices C, D, E, and F provide detailed data on the CRAC and supplemental airlines relevant to passengers, express, freight, and mail for scheduled and nonscheduled operations. Appendix G contains aggregate totals used for forecasting market demand.

2. GNP data are published periodically by the Department of Commerce, Bureau of Economic Analysis. Appendix H contains current and deflated (1972 dollars) GNP data.

3. Costs associated with government sponsorship in terms of the initial cost differential between a passenger version (B-747A and B-747B) in contrast to a B-747C convertible were available for the 1973 time frame as outlined in Pugh's study (60:38). Updated cost information was requested from The Boeing Company by the researchers; however, the information was classified as "privileged" and not divulged. Hence, wholesale price indices for transportation equipment published by the Bureau of Census, U.S. Department of Commerce, were used to economically escalate 1973 costs. Recurring costs representing costs associated with increased operating

empty weight of a convertible aircraft and other expenses were based on actual air carrier operating experience as outlined in numerous issues of Aviation Week and Space Technology.

4. Aircraft operating characteristics were obtained from Jane's All the World's Aircraft 1972-73 and several informative documents provided by The Boeing Company.

STUDY DESIGN

The growth of the U.S. economy is reflected by the GNP. Rand Corporation's 1972 study on energy consumption focused on freight transport and found deflated GNP as an excellent explanatory variable for forecasting airfreight growth (68:11-17). When linked to airfreight volume, the Rand "GNP Model" performed extremely well in predicting actual energy demand for the airfreight mode of transportation for the 1947 to 1968 time frame (68:43-49). Basic concepts and methodology employed by the Rand study were used in this thesis to generate market forecasts based on an average annual increase in deflated GNP. However, the overall approach to resolving the research question was tempered by the following excerpt from a speech presented by a member of the Board of Governors of the Federal Reserve System at the thirteenth annual Economic Outlook Conference on June 23, 1976:

> All forecasting, whether judgmental or econometric, basically relies on the application of historical relationships to emerging economic developments, implicitly

> assuming that these relationships will be reasonably maintained in the future. The facts are that economic relationships are rather loose, and are subject to frequent abberations and unexpected change. Because of this, economists simply cannot count on their ability to forecast economic events very far into the future with any high degree of reliability [66:27].

Taking into consideration the inherent uncertainty of relying on historical relationships, the researchers designed a computer model through which a cost sensitivity analysis could be performed. The computer model was developed in five distinct phases as follows:

Phase I. The Rand study determined there was a high coefficient of determination (.99) for the regression of air cargo ton-miles on deflated gross national product prior to 1969 (68:11). Since that time, however, both the air passenger and air cargo markets have been plagued with adverse economic conditions which have affected growth. Phase I was limited to verifying the continued validity of the Rand "GNP model" for use in generating forecasted air carrier traffic for the years following 1968.

Phase II. This phase involved generation of expected market conditions for various average rates of deflated annual GNP growth (and decline). Each market forecast was translated into upper and lower confidence limits of market activity based on the log-linear regression model equations yielded by Phase I.

Phase III. The confidence intervals established for forecasts in Phase II were translated into numbers of new aircraft required by

air carriers to service passenger and air cargo transportation requirements. Three different situations were introduced into the computer model ranging from strictly long range WB aircraft to an assortment of short/medium NB, short/medium WB, and long range WB aircraft. Each situation encompassed varying levels of projected deflated annual GNP growth. Chapter III provides a detailed outline of the various situations employed to depict air carrier selection of aircraft to service market demand.

Phase IV. The additional number of passenger aircraft required by air carriers to service passenger requirements represented potential convertible aircraft. Aircraft were generated based on a series of equations depicting annual aircraft productivity and the situations under study. Initial government sponsorship costs were then derived based on an annual 6 percent economically escalated cost differential associated with the purchase of a B-747C convertible instead of a B-747-200B passenger model by the air carrier. After accounting for lower hold cargo of passenger aircraft, the net market forecast for cargo ton-miles was translated into numbers of pure freighter aircraft required to service air cargo requirements.

Phase V. The last phase of the model involved a time phased flow of convertible aircraft transitioning to a pure freighter configuration as the demand for pure freighter aircraft was generated by market conditions. In reality, a convertible aircraft would likely be used to

service both passenger and cargo requirements. However, the model was developed in the context that once a convertible was used in a freighter mode it was considered as continually operated in that mode. Withdrawal of a convertible aircraft from servicing passenger requirements to meet the demand for a freighter was compensated for by a corresponding increase in the number of passenger aircraft to service passenger requirements. Government sponsorship of operating costs were calculated for convertible aircraft operating in a passenger mode beginning in the year since the date the convertible was purchased and terminates when a convertible was transitioned to cargo. Overall operating costs were based on the difference in OEW between the B-747-200B and B-747-200C aircraft. A cost per ton-mile of OEW was derived considering current operating experience of B-747-100 users and is explained in detail in the following chapter. The major benefit to the government of increased strategic airlift capability was not evaluated in monetary terms. However, total cash flows represented by initial and recurring government sponsorship costs and air carrier reimbursements were examined by calculating the discounted present value for each situation and level of economic activity.

ASSUMPTIONS

1. The National Strategic Airlift Resource deficit was valid based on the references cited throughout this thesis.

2. The CRAF requirement equivalent to the cargo carrying capability of 100 B-747 aircraft would remain constant. Any additional military airlift capability generated as a result of modifications or new aircraft would not affect the CRAF requirement.

3. The Certificated Route and Supplemental Air Carriers adequately represent the aircraft population from which CRAF requirements for aircraft are drawn. Further the proportion of revenue passenger miles flown by the air carriers would remain constant in relation to the total U.S. civil air fleet.

4. Forecast error associated with the projection of passenger revenue miles and cargo ton-miles was normally distributed with an expected value of zero.

5. Aircraft purchased by air carriers to meet expected demand would generally follow one of the three situations examined with the computer model.

6. Air carriers would purchase convertible rather than passenger aircraft if the government paid the difference in initial investment and annual operating costs for convertibles operated in the passenger mode.

7. Helicopter carriers would continue to represent an insignificant portion of the combined Certificated Route and Supplemental Air Carrier aviation statistics.

8. An average annual 6% inflation factor would remain constant throughout the time period examined.

9. The pricing policy of aircraft manufacturers remains static insofar as the cost differential between passenger and convertible aircraft.

10. The freighter mode of a convertible aircraft would be used by air carriers to service increases in market demand for air cargo transportation rather than procurement of pure freighter aircraft. Further, once a convertible aircraft was used in a freighter mode, the model assumed its continued use as a pure freighter.

11. Basic equations formulated in Chapter III to depict aircraft productivity and associated values were representative of real world conditions.

12. Historical data obtained from data sources outlined in the data requirements section of this chapter were accurate.

LIMITATIONS

1. A breakdown in the relationship of the demand for air transportation and deflated GNP would severely degrade the model's ability to project estimated government sponsorship costs. Such a breakdown could be brought about by changes in transportation technology resulting in lower utilization of aircraft even though there are significant increases in real U.S. national growth.

2. The reliability of GNP forecasts exceeding one or two years is questionable; therefore, the model is limited to projecting

market demand based on average rates of annual GNP growth.

3. The model developed does not attempt to account for, nor quantify in monetary terms, those intangible benefits accruing to the U.S. government as a result of an enhanced strategic airlift capability.

CHAPTER III

COMPUTER MODEL DESCRIPTION

A computer model was developed to allow rapid processing and manipulation of key variables to permit resolution of the research question. Further, the model provided a simple, straightforward approach to ascertaining the impact of three distinctly different situations relating to strategic airlift enhancement through government sponsorship of a wide-bodied (WB) convertible aircraft. Appendix I provides a comprehensive flow diagram of the computer model. Consistent with the research question, the model also provided a means of determining the time interval and associated costs necessary to achieve a strategic airlift productive cargo capability equivalent to 100 long range international WB cargo capable aircraft. The earlier Mitchell (39) recommendation of air carrier reimbursement was incorporated to determine the feasibility and impact on the government program.

As in depth understanding of the mechanics of the computer model is not prerequisite to interpretation of the results outlined in the following chapter; however, the reader should be aware of the rationale used in developing critical factors that provide the foundation

for basic equations employed in the process of determining forecasted aircraft requirements. Appendix J summarizes volume and weight characteristics of aircraft frequently referred to throughout the remaining chapters.

Three situations were examined which would impact significantly on the U.S. National Strategic Airlift Resource in terms of strategic airlift capability available from CRAF resources during a national emergency. The following provides a brief description of each:

1. Situation A. The least likely real world situation to occur was considered first. As new requirements for additional aircraft were generated based on economic forecasts, specified load factors, and utilization rates, annual requirements were considered as strictly new orders for long range WB passenger, convertible, or freighter aircraft.

2. Situation B. This situation more closely depicted what should occur given a market mix of predominantly short/medium range NB and long range WB aircraft. For this situation, forecasted annual passenger revenue miles (PRM) were reduced by the expected number of PRM that would be flown by NB aircraft. The remaining amount of air traffic was serviced by long range WB passenger, convertible, or freighter aircraft.

3. Situation C. The final situation represented the case where new orders for long range WB passenger, convertible, or freighter aircraft were reduced as a result of short/medium range WB and NB aircraft. This situation was designed to depict the real world as closely as possible.

BASIC EQUATIONS

The computer model was constructed based on a series of equations developed to depict: (1) the expected demand for air passenger and cargo service for various levels of real national growth, and (2) the ability of air carriers to satisfy expected demand as a function of the productivity of the aircraft they possessed or purchased in a given year. The equations for aircraft productivity were developed based on one fundamental relationship which is inherent in measuring transport efficiency; namely, the rate of producing air transportation in net ton-miles per hour is equal to the product of payload (net tons) times the speed of the aircraft in miles per hour. When viewed in the context of maximizing net ton-miles of productivity per aircraft, the basic relationship encompasses three technological capabilities: (1) capacity, (2) utilization, and (3) speed. Capacity is proportional to the size of the aircraft, while utilization is dependent on the air carrier's ability to consistently load the aircraft to capacity and operate the aircraft as many hours per day as possible within the constraints of turn-around time, maintenance downtime, and scheduling

inefficiencies. Average airborne speed (effective speed) is dependent on varying conditions such as type of aircraft, engine efficiency, propulsive-effort variations due to weather conditions, and route layout including hop length which dictates the frequency of ascent and descent (36:255-256,266-267).

Log-linear Regression Forecast

The main computer program utilized two log-linear equations derived through the regression of PRM on deflated GNP (1972 dollars) and cargo ton-miles on deflated GNP. Through an incremental increase in annual GNP ranging from -1.0 percent to 6.0 percent, forecasts for the respective independent variable (PRM or cargo ton-miles) were generated for each year through 1990. The model form of the log-linear equation used was as follows:

$$\ln(Y) = a + b \cdot \ln(GNP),$$

where a and b were estimated coefficients, Y the dependent variable (either PRM in millions or freight and mail volume in millions of ton-miles), and the explanatory variable, GNP, was measured in billions of 1972 dollars.

Passenger Revenue Mile Aircraft Productivity

Once a forecast was generated, the quantity of airframes required to service the requirement was achieved by dividing the

requirement by the PRM aircraft productivity factor. Similar rationale used in deriving the productivity factor was employed for enplaned lower hold cargo and ton-mile productivity of freighter aircraft. All three equations were derived from a combination of three elements; namely, (1) aircraft capacity, (2) aircraft speed, and (3) aircraft utilization (i.e., passenger utilization of an airline's services and an airline's utilization of aircraft). The basic linear equation for annual PRM aircraft productivity was developed as follows:

Aircraft Capacity	x	Average Airborne Speed	x	Average Revenue Passenger Load Factor	x	Average Daily Utilization Factor (in flight)	x	365 (Days per Year)

= PRM Generated by One Aircraft per Year

The factors used for determining the productivity of the average NB, long range WB, and short range WB, were the Boeing 727-200, Boeing 747, French/German A300-B Airbus, and Lockheed L-1011.[1] Initial values for the basic elements of the equation for each type of aircraft were derived as follows:

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[1]Eastern Airlines leased four A-300 aircraft with delivery beginning in August 1977. Following a trial period and comparison of the A-300 with existing Eastern aircraft such as the B-727 and L-1011, the airline will decide if the aircraft meets the airline's needs. Eastern's President and Chief Executive Officer, Frank Borman, recently indicated the airline would need over 50 aircraft similar to the A-300 (e.g., a short/medium WB type aircraft) to cope with a 5 percent annual growth rate in PRM over the next 10 years (26:30).

1. Aircraft Capacity (Seats per Aircraft).

a. Boeing 747. Three typical arrangements of the 747 cabin interior range from mixed class seating of 385 passengers to 500 economy class passengers with minimum service facilities such as galleys (7:26). The 747 equivalent selected for computation purposes seated 423 economy class passengers, 10 abreast at 34 inch spacing. The rationale for selection of the economy class configuration centered on current FFA projections of higher density seating in the mid 1980s (41:25).

The use of 423 seats represented a conservative estimate in view of 1975 CAB statistics which indicated 1,759,077 out of 2,240,505 (78.5%) revenue aircraft miles flown by the CRAC were by mixed class aircraft. Therefore, the argument could be made that a mixed class WB aircraft would be a more realistic estimate (23:80). However, coach plus economy passengers accounted for 82 percent of scheduled domestic passenger revenue miles flown and 92.5 percent of scheduled international/territorial passenger revenue miles flown. Both percentages have remained relatively stable over the past seven years with a slight upward trend toward greater utilization of coach and economy seating (23:79). The average seat capacity for 747 aircraft possessed by U.S. airlines during the last quarter of 1976 ranged from a low of 342 for United Airlines to a high of 375 for Pan American Airlines (56:34). The Boeing B-747 passenger aircraft accounted for 16.5 percent of all PRM flown in 1976 (13:1; 53:32; 54:40; 55:36; 56:34).

b. Boeing 727-200. The B-727-200 version of Boeing B-727 series of aircraft was selected as a standard NB aircraft. In contrast to the earlier B-727-100 version with a capacity of 70 to 131 passengers, the B-727-200 can carry between 120 to 189 passengers. During 1976, the fleet of B-727-200 aircraft flew 33.887 billion PRM; however, average seat capacity on the aircraft ranged from only 121.9 (Western) to 135.8 (National). Both models flew a combined total of 58.06 billion PRM in passenger service of the CRAC during 1976 which represented 35.7 percent of all PRM flown (13:1; 46:32-33). The trend toward higher density aircraft seating consistent with FAA forecasts (41:25) appears to be manifesting itself through increased interest by airlines in short/medium range NB aircraft such as the 727-200 (69: 148). Therefore, the seating capacity for a standard NB aircraft was set at 130 passengers based on weighted average.

c. Lockheed L-1011 and Airbus Industries A-300. The use of short/medium range WB aircraft by U.S. airlines to service domestic traffic requirements decreases the amount of potential long range strategic airlift capability which would otherwise be available had the airline purchased a longer range aircraft. Specifically, the short/medium range versions of the A-300B4 Airbus and L-1011 Tristar provide mixed-class seating for 237 and 256 passengers, respectively. The average seat capacity of the L-1011 flown in passenger service during 1976 ranged from 230 (Trans World) to 270 (Eastern)

(56:35). Hence, the standard seating for a short/medium range WB aircraft was estimated at the average of 250. The L-1011 flew 6.9 percent of the PRM flown in 1976 (13:1; 53:33; 54:41; 55:37; 56:35).

2. Average Airborne Speed. The average airborne speed of aircraft in scheduled domestic passenger/cargo CRAC service was 403 miles per hour in 1975. Aircraft flown on international routes have exceeded 468 miles per hour since 1966 and in 1975 the average was 482 miles per hour (23:73). Boeing uses an average speed of 487.5 miles per hour when comparing productivity of the B-747F with the B-707-320 (8:60). Actual operating experience indicated average airborne speed increased as the average hop length increased. Each data point on Figure 3 depicts the relationship between speed and hop length for airlines operating WB aircraft during the last quarter of 1976. Further, the figure provides a comparison with the B-727-200 NB aircraft operated by Delta, American, Trans World, United, and Northwest.[2] Overall, the average airborne speed of the entire B727-200 fleet was 421.95 miles per hour in 1976. Average hop length was 495.97 miles. A cursory analysis of Figure 3 illustrates the range over which the airlines elect to utilize various types of aircraft. The weighted average airborne speed outlined in Figure 3 for each type of

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[2]The average airborne speed for the B-727-200 was derived by dividing revenue miles flown by total revenue hours flown. Average trip length was calculated by dividing revenue miles flown by total revenue departures (46:32-33).

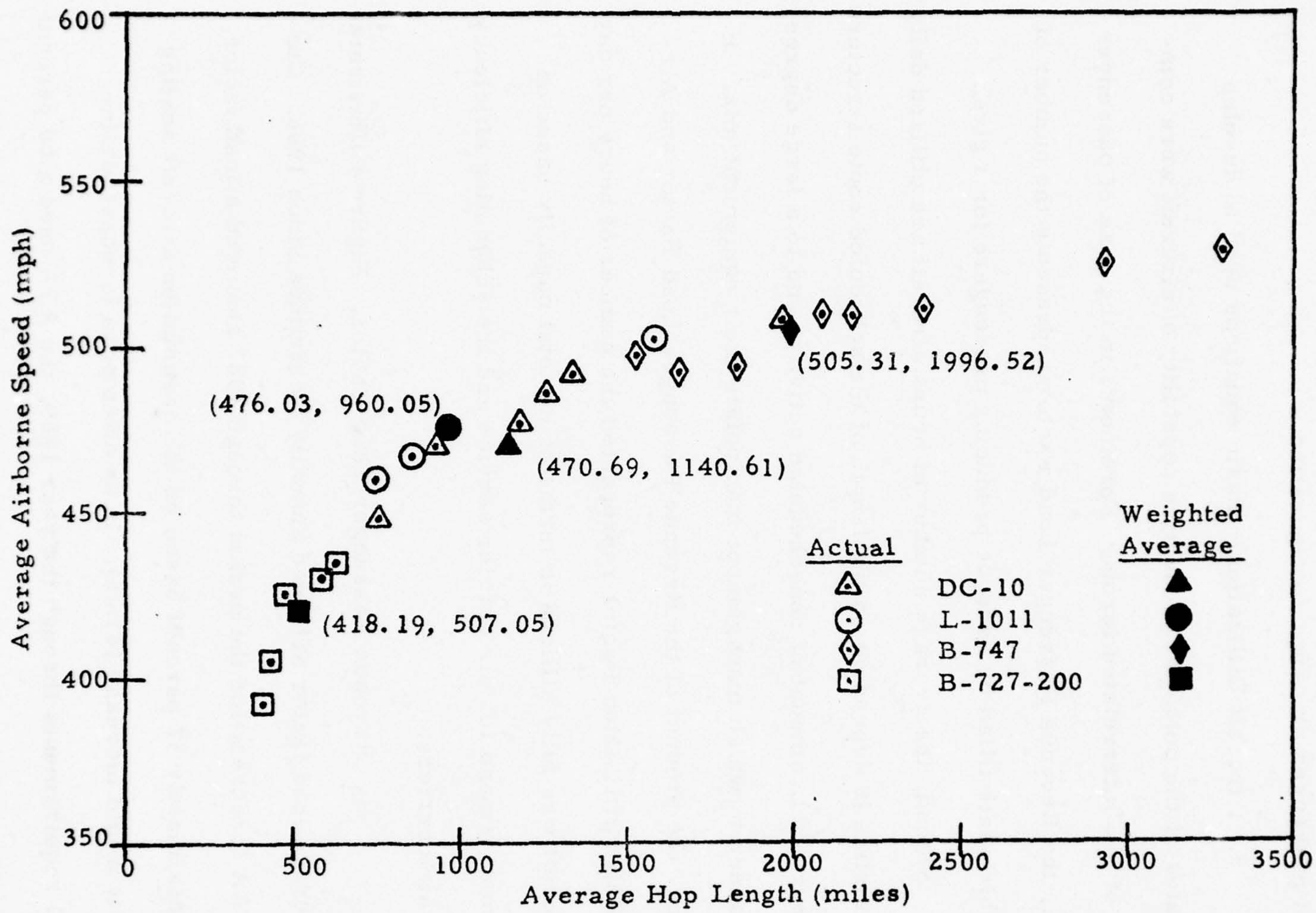

Fig. 3. The Relationship of Average Hop Length vs Average Airborne Speed
Source: Aviation Week and Space Technology (46:32-33; 56:34-35)

aircraft was used in the computer model for all basic equations regardless of passenger or cargo configuration.

3. Aircraft Utilization. Basic equations used to develop estimates of the potential productive capability of aircraft were composed of two interrelated terms. Foremost, in the case of passenger traffic, the Revenue Passenger Load Factor represents the number of available seats filled by revenue producing passengers for a given flight. Second, the average number of hours aircraft are utilized daily by an airline is dependent on the length of the scheduled route structure to be serviced, amount of nonscheduled activity, and to a large degree, the manner in which management manipulate their equipment mix. In essence, the product of the Revenue Passenger Load Factor and Aircraft Daily Utilization Factor represented the number of hours per day an aircraft was fully utilized in terms of its total capacity based on consumer demand for air carrier service and the scheduling efficiency of the air carriers.

a. Revenue Passenger Load Factor. Figure 4 illustrates the average load factor achieved annually by airlines since 1966. Current FAA forecasts for the period through 1987 assumed a load factor of approximately 57 percent based on the assumption aircraft seating capacity would increase (41:24). In an attempt to forecast airline capital requirements through the year 1989, the ATA used a 60 percent load factor predicated on the rationale that an average load factor higher

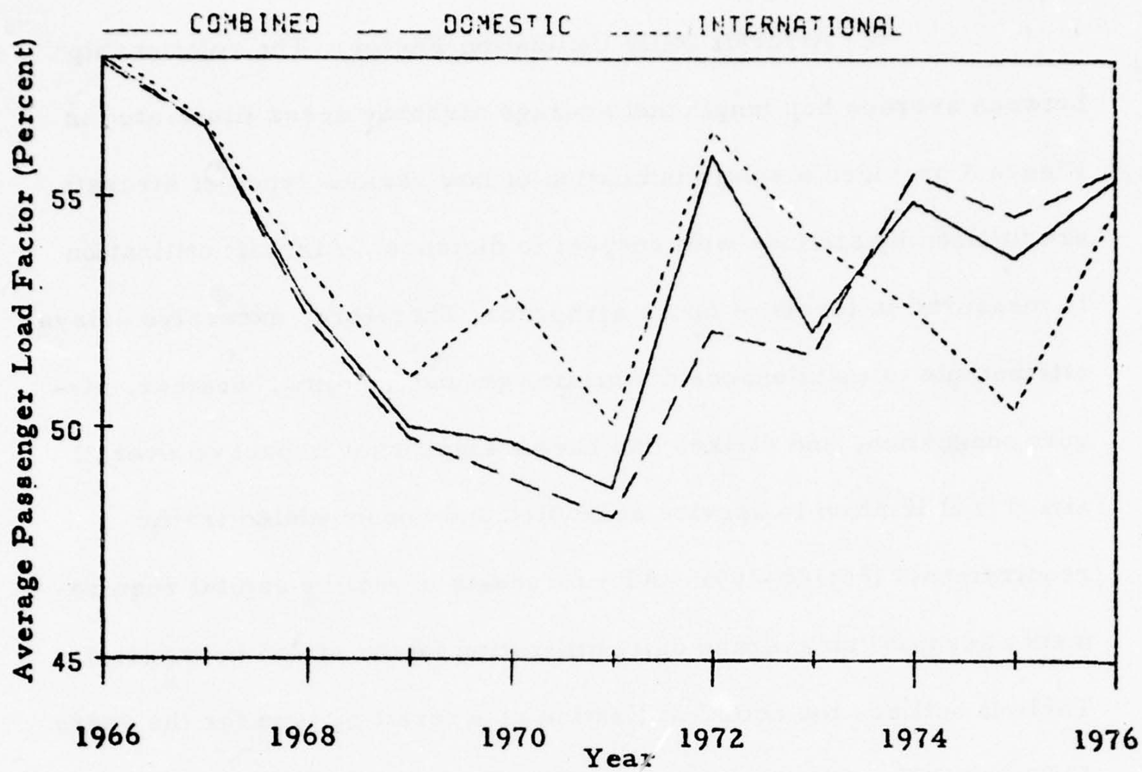

Fig. 4. Certificated Route Air Carrier Revenue Passenger Load Factor (1966-1976)

than 60 percent would result in a reduction in public service such that many flights would be consistently booked to maximum capacity. Since the major objective of the ATA study was to develop a conservative prediction of capital requirements, the ATA emphasized a lower average load factor would result in higher aircraft capital requirements (1:3). The ATA rationale appears sound provided there is no drastic change in regulation of air carriers with regard to mandatory minimum utilization of aircraft. Consequently, an initial value of a 60 percent Revenue Passenger Load Factor was employed in the computer model.

b. Aircraft Daily Utilization Factor. The relationship between average hop length and average airborne speed illustrated in Figure 3 provided a subtle indication of how various types of aircraft are utilized by airlines with respect to distance. Aircraft utilization is measured in terms of hours airborne. Therefore, excessive delays attributable to maintenance downtime, ground handling, weather, airport congestion, and strikes can have a significant impact on overall aircraft utilization to service scheduled and nonscheduled traffic requirements (65:168-169). ATA forecasts of airline capital requirements assumed an average daily utilization factor of 7.5 hours (1:3). Table II outlines the actual utilization of aircraft by type for the years 1973 and 1975. The aircraft identified by specific type represented 76.7 percent of the total 2,679 fixed-wing aircraft in the U.S. Civil Air Carrier Fleet in 1975 and accounted for 87.9 percent of the 6.1 million hours of flight time (23:53, 58, 68-69). Further, Table II highlights the relatively higher utilization of the B-707 and B-747 which are used frequently for long range hops. The B-747 worldwide fleet of 247 aircraft operated by 40 different airlines achieved an average cumulative fleet utilization of 9.05 flight hours per day since the beginning of revenue operations in 1970 (7:6). As of August 1976, the average cumulative B-747 fleet utilization had increased to 9.1 flight hours per day (12:12). In view of the distinct difference in daily utilization of short/medium and long range aircraft, the basic equation

Table II
Aircraft Daily Utilization Rate and Percentage of Total Annual Hours Flown by Type of Aircraft in the U.S. Air Carrier Fleet
(23:53, 58; 29:17, 18)

	1973		1974		1975	
Type of Aircraft (1)	Daily[a] Utilization Rate (hours) (2)	Percentage of Total Fleet Hrs Flown (%) (3)	Daily[a] Utilization Rate (hours) (4)	Percentage of Total Fleet Hrs Flown (%) (5)	Daily[a] Utilization Rate (hours) (6)	Percentage of Total Fleet Hrs Flown (%) (7)
B-747	9.57	5.8	8.55	5.3	9.33	5.5
DC-10	6.95	3.5	7.17	4.6	7.08	5.3
L-1011	3.60[b]	0.9	5.25	2.1	6.22	2.9
B-707	8.77	15.2	8.98	15.1	8.50	13.5
DC-8	8.86	11.3	7.73	9.5	7.04	8.9
DC-9	7.50	14.0	7.07	15.7	6.84	14.1
B-737	6.16	5.1	5.92	5.3	5.83	5.2
B-727	7.18	28.9	7.04	31.4	6.80	32.5
Other	4.96	15.3	4.17	11.0	4.47	12.1
Total		100.0		100.0		100.0

[a]The daily utilization rate was based on total flight time flown by a specific type aircraft divided by the product of total aircraft of that type used during the last quarter multiplied by 365 days.

[b]The utilization rate for the L-1011 is not meaningful due to the small number of aircraft possessed and phase in of new aircraft throughout the year.

for aircraft productivity in terms of annual PRM provided for a daily utilization rate of 9.1 hours for long range WB aircraft and 7.5 hours per day for short/medium range NB and WB aircraft.

Table III summarizes the values used in the computer model for conversion of forecasted PRM into required aircraft to service market demand.

Cargo Ton-mile Aircraft Productivity

Once the number of passenger aircraft was determined for each year based on annual forecasts, an estimate of available lower hold cargo capacity was prerequisite to generating the number of wide-bodied convertible or freighter aircraft required to service annual demand for air cargo service. Two basic equations were developed to depict the total cargo ton-mile capability of passenger and freighter aircraft. One equation provided an estimate of lower hold cargo ton-miles generated by a passenger aircraft annually. The second equation permitted translation of forecasted ton-miles into quantities of freighter aircraft after deducting lower hold capability. In general, the rationale used in selecting certain values was similar to the development of the PRM productivity conversion factor; however, due to the nature of service (cargo vs passengers), several additional factors were included to allow consideration of cargo volume and weight density.

Table III
Summary of Annual Passenger Revenue Mile (PRM) Productivity Factors for Selected Short/Medium and Long Range Passenger Aircraft

Type Aircraft (1)	Aircraft Capacity (Passengers) (2)	Average Airborne Speed (mph) (3)	Average Revenue Passenger Load Factor (4)	Average Daily Utilization Factor (hrs) (5)	Days Per Year (6)	Aircraft Annual Passenger Mile Productivity (PRM) (7)
Long Range WB (B-747)	423	505.31	60%	9.1	365	425,974,662.5
Short/Medium Range WB (L-1011 or A-300B2)	250	476.03	60%	7.5	365	195,469,818.8
Short/Medium Range NB B-727-200	130	421.95	60%	7.5	365	90,096,873.8

Source: Column 7: The annual productivity figure is the product of columns 2 through 6.

1. Lower Hold Cargo Ton-mile Productivity. The theoretical lower hold capacity of a passenger aircraft is reduced considerably as a result of (1) the lack of demand coinciding with passenger routes, and (2) the relative position of airports (i.e., an airport on a multistop route may use only a small portion of capacity with the remaining used by other airports) (42:16). The relationship between capacity, utilization and speed resulted in the general equation,

$$\left[\begin{array}{l}\text{Total Volume}\\ \text{of Lower Hold}\\ \text{Compartments}\end{array} - \left(\begin{array}{l}\text{Aircraft}\\ \text{Capacity}\\ \text{(Passengers)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Revenue}\\ \text{Passenger}\\ \text{Load Factor}\\ (\%)\end{array} \times \begin{array}{l}\text{Baggage}\\ \text{Volume in}\\ \text{Lower}\\ \text{Hold Per}\\ \text{Passenger}\end{array}\right)\right]$$

$$\times \begin{array}{l}\text{Average}\\ \text{Cargo}\\ \text{Density}\\ \text{(lb/cu ft)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Airborne}\\ \text{Speed}\\ \text{(mph)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Daily}\\ \textit{Utilization}\\ \text{Factor}\\ \text{(Hours)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Lower}\\ \text{Hold}\\ \text{Enplanement}\\ \text{Load Factor}\end{array} \times \begin{array}{l}\text{Days}\\ \text{Per}\\ \text{Year}\end{array}$$

$$\div\ 2000 \begin{array}{l}\text{Pounds}\\ \text{Per}\\ \text{Ton}\end{array} = \begin{array}{l}\text{Lower Hold Cargo Ton-Miles}\\ \text{Generated By One Passenger}\\ \text{Aircraft Per Year.}\end{array}$$

The same values for the variables average aircraft capacity, revenue passenger load factor, airborne speed, and daily utilization used for passenger aircraft were applied to cargo computations (see Table III). Values for the remaining variables were derived as follows:

a. Total Volume of Lower Hold Compartments, Baggage Volume in Lower Hold, and Average Cargo Density. The total volume

of lower hold compartments for various aircraft was obtained as outlined in Appendix J. Depending on the aircraft configuration, payload varies in relation to distance traveled and, in the case of a passenger aircraft, the number of passengers enplaned. For example, the lower lobe payload of a passenger B-747 is 112,750 pounds; however, the maximum volume of the lower lobe is 6,190 cubic feet. The volume-to-payload relationship equates to 18.2 pounds per cubic foot. As the number of passengers carried are increased, there is a corresponding decrease in usable volume for revenue cargo in the lower hold. Boeing used a standard factor of 5 cubic feet, per passenger in determining residual cargo capability (12:13). In the case of the B-747 passenger aircraft, 423 economy class passengers equate to 2,115 cubic feet of baggage with 4,075 cubic feet remaining for revenue producing cargo in the lower hold; however, the remaining capacity is further constrained by the maximum allowable weight relative to the size of cargo module. As an example, the maximum volume-to-weight for an 88" x 108" x 96" MIL 463L main deck pallet is 20.60 pounds per cubic foot. On the surface, the constraint of 20.60 lb/cu ft would seem favorable in terms of maximizing the weight of the payload carried if such a volume-to-weight could be achieved. Extensive studies were conducted by Boeing to evaluate actual cargo density of air freight carried by air cargo carriers. After observing over 10,500 flights of B-707/DC-8 sized aircraft and tabulating data on the weight, and

volume of more than 107,000 pallets and containers, Boeing concluded the projected cargo density for a B-747-200F freighter would "range from 8 to 12 pounds per cubic foot with a mean average of 9.8 pounds per cubic foot for international operations [8:31]." Figure 5 illustrates that nearly 90 percent of all pallets evaluated had a cargo density of less than 14 pounds per cubic foot.[3]

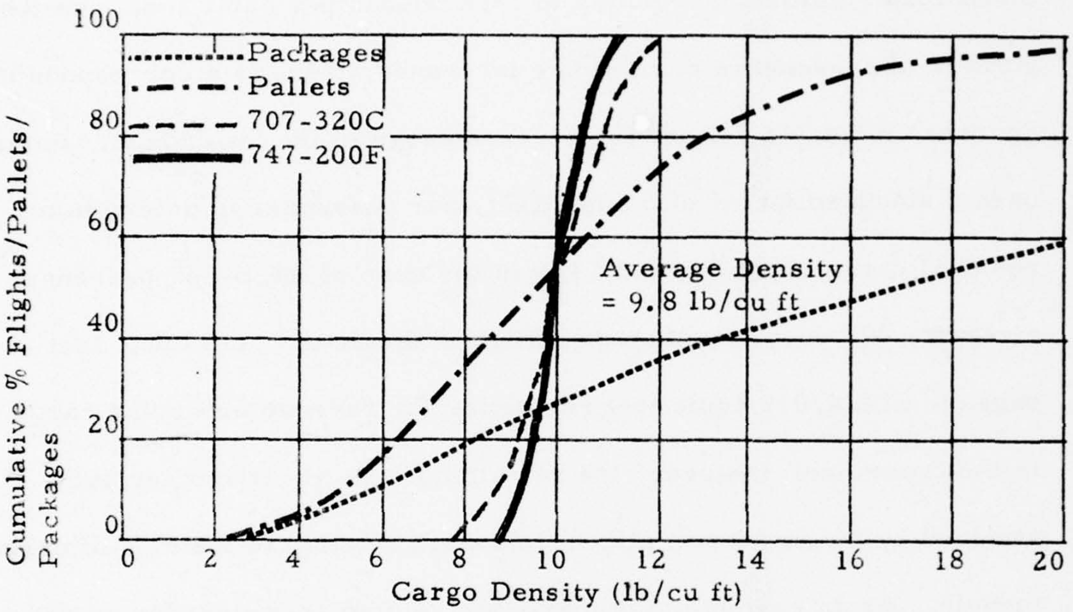

Fig. 5. Effect of Aircraft Size on Cargo Density Distribution (8:31)

b. Average Lower Hold Enplanement Factor. Civil Aeronautics Board (CAB) U.S. airline service segment data was

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[3]This finding compares favorably with British European Airways' study of 112 flights in 1962 which found a mean density of 12.25 pounds per cubic foot with a standard deviation of 4 pounds (65:183-185).

reviewed for the 25 most active airports. The data indicated an average lower hold enplanement factor of 18.5 percent for domestic service and 26.9 percent for international service during the period April 1974 through March 1975 (42:25). Table IV provides a comparison of system averages with three major hubs. The significant conclusions

Table IV
CAB Airline Service Segment Data,
April 1974-March 1975
U.S. Flag Carriers (42:18-25)

	Domestic (DOM) or International (INT)	System (25 Hubs)	Los Angeles	Chicago	New York/Newark
No. of Passenger Flight Departures	DOM	2,272,102	129,047	261,670	224,336
	INT	78,555	5,507	4,949	20,081
Average Seats Available Per Departure	DOM	118.5	142.1	120.2	122.5
	INT	163.5	209.6	158.0	185.8
Average PAX Load Factor (%)	DOM	47.6	46.8	50.2	51.8
	INT	46.2	43.5	53.7	50.5
Average Lower Hold Aircraft Cargo Capacity (lbs)	DOM	8,244.8	11,997.9	8,991.1	8,231.3
	INT	13,491.7	19,208.3	14,188.5	16,134.2
Average Lower Hold Cargo Enplanement Load Factor (%)	DOM	18.5	23.9	20.2	20.0
	INT	26.9	24.7	32.2	33.8

made by the FAA were: (1) theoretical lower hold capacity for aircraft flying domestic routes is underutilized, (2) lower hold utilization for aircraft flying international routes is greater than the lower hold

utilization on domestic routes, and (3) the greater the average lower hold cargo capacity, the higher the average lower hold cargo enplanement factor. FAA forecasts for air freight demand assumed a steady increase in the average lower hold enplanement load factor as outlined in Table V. The values selected for use in the basic equation were 20 percent, 25 percent, and 35 percent for the short/medium range NB aircraft, short/medium WB aircraft, and long range WB aircraft, respectively. Table VI summarizes the values used in derivation of the annual lower hold cargo ton-miles generated by the three types of passenger aircraft.

Table V
FAA Actual and Forecasted Average Lower
Hold Enplanement Load Factors (42:30)

Year	Average Lower Hold Enplanement Load Factor	
	Domestic Service	International Service
April 74-March 75	18.5	26.9
1977	20.0	30.0
1982	22.0	35.0
1987	24.0	40.0

2. Ton-mile Freighter Aircraft Productivity. The basic equation derived for estimating the number of WB freighter or convertible aircraft to service the remaining freight requirements was as follows:

$$\left(\begin{array}{l}\text{Cargo}\\ \text{Capacity}\\ \text{(cu ft)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Cargo}\\ \text{Load}\\ \text{Factor}\\ (\%)\end{array} \times \begin{array}{l}\text{Average}\\ \text{Cargo}\\ \text{Density}\\ \text{(lb/cu ft)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Airborne}\\ \text{Speed}\\ \text{(mph)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Daily}\\ \text{Utilization}\\ \text{Factor}\\ \text{(hours)}\end{array} \times \begin{array}{l}\text{Days}\\ \text{Per}\\ \text{Year}\end{array}\right) \div 2{,}000 \begin{array}{l}\text{Pounds}\\ \text{Per}\\ \text{Ton}\end{array} = \begin{array}{l}\text{Cargo Ton-miles Generated}\\ \text{By } \underline{\text{One}} \text{ Aircraft Per Year}\end{array}$$

The values used for average cargo density and average airborne speed were the same as those determined for passenger aircraft. The remaining variables required modification to take into consideration the configuration of the aircraft and air carrier utilization. In the case of cargo capacity, both the B-747-200C convertible and B-747-200F freighter have a combined main deck and lower hold cargo capacity 23,630 cubic feet (see Appendix J).[4] The values required for a realistic assessment of aircraft utilization were determined based on past performance.

a. Average Cargo Load Factor. In contrast to the Revenue Passenger Load Factor, the average cargo load factor tends to be higher for cargo operations. As of 1 January 1977, the Monthly Civil Reserve Air Fleet (CRAF) Capability Summary published by

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[4] Technically, the relationship between cargo capacity and a 10 lb/cu ft average cargo density becomes inoperative if the hop length exceeds approximately 2,900 miles. At that point, cargo capacity is constrained by a payload weight vs range relationship which would require either a lower average cargo density or less volume (7:46).

Table VI
Summary of Annual Lower Hold Cargo Ton-mile Productivity for Selected Short/Medium and Long Range Passenger Aircraft

Type Aircraft (1)	Total Volume of Lower Hold Compartments (cu ft) (2)	Aircraft Capacity (Passengers) (3)	Average Revenue Passenger Load Factor (4)	Baggage Volume in Lower Hold Per Passenger (cu ft) (5)	Average Cargo Density (lb/cu ft) (6)	Average Airborne Speed (mph) (7)	Average Daily Utilization Factor (8)	Average Lower Hold Enplanement Factor (9)	Days Per Year (10)	Annual Lower Hold Cargo Ton-mile Productivity (11)
Long Range WB B-747B	6,190	423	60%	5	9.8	505.31	9.1	35%	365	14,164,773.7
Short/ Medium Range WB (A-300B2)	4,869	250	60%	5	9.8	476.03	7.5	25%	365	6,575,311.5
Short/ Medium Range NB (B-727-200)	1,485	130	60%	5	9.8	421.95	7.5	20%	365	1,239,525.1

Source: Column 11: The annual productivity figure is [[Col. (2)-(Col. (3) x Col. (4) x Col. (5))] x Col. (6) x Col. (7) x Col. (8) x Col. (9) x Col. (10)] divided by 2000.

Hq MAC/XPW, indicated there were two convertible and 12 freighter B-747 aircraft operated by U.S. airlines. The two convertibles were operated by a supplemental carrier (World Airways), and five of the 12 CRAC freighters were operated by all-cargo carriers (Flying Tigers--3 and Seaboard World--2). During 1976, all-cargo carriers flew 35.6 percent of all aircraft revenue miles flown by CRAC aircraft operated in an all-cargo mode. Further, the all-cargo carriers achieved an average cargo load factor of 63.0 percent for combined domestic and international operations. Although the all-cargo carriers accounted for only 27 percent of total cargo ton-miles flown in scheduled and nonscheduled service, they did, in the opinion of the researchers, depict a minimum average cargo load factor which was be achieved through judicious management during a stable economic climate (13:1-3). Figure 6 outlines the average cargo load factor achieved by the all-cargo carriers since 1966. In the interest of ensuring a conservative estimate of additional freighters necessary to satisfy residual cargo ton-miles annually, the load factor was arbitrarily escalated to 70.0 percent for use in the basic equation.

b. Average Daily Utilization Factor. Daily utilization of aircraft operated in the cargo mode tends to be higher than for aircraft operated in a passenger configuration. An analysis of all-cargo carrier operations indicated the Flying Tiger fleet of three B-747F, six DC-8-63F, and eleven DC-8-63CF aircraft had a cumulative

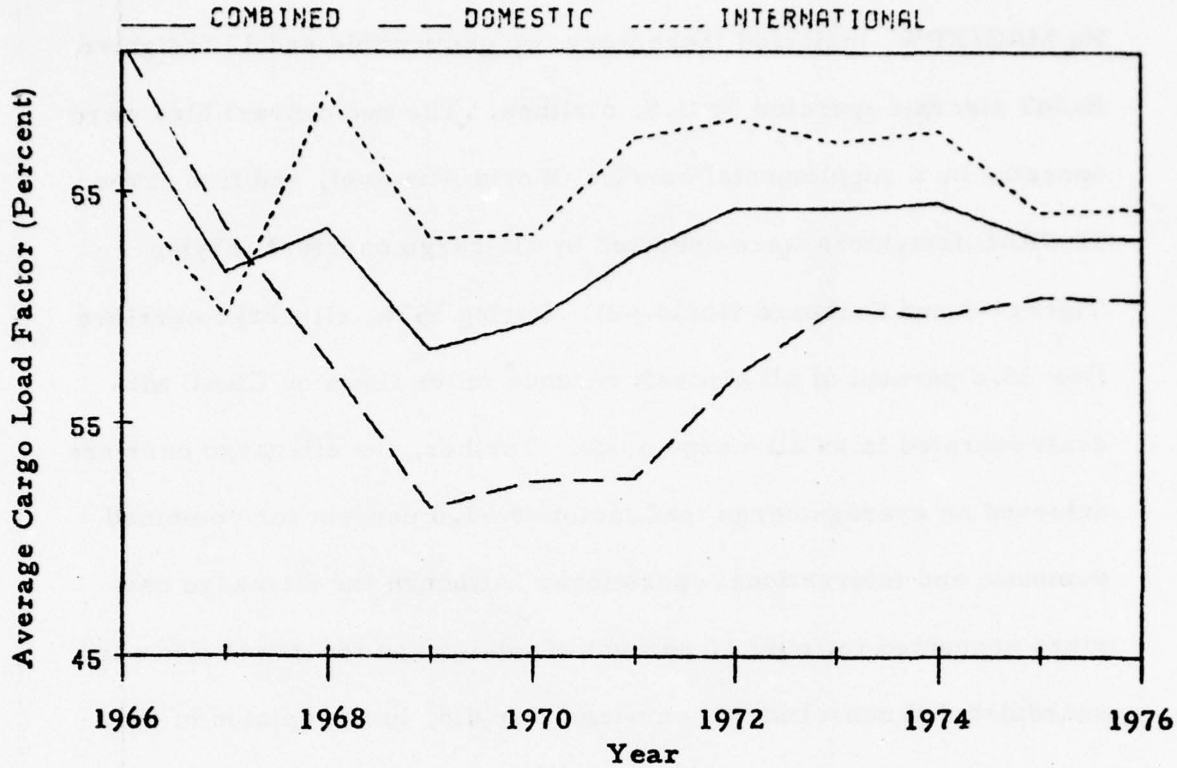

Fig. 6. Average Annual Cargo Load Factor for All-Cargo Carriers Operating in Scheduled Service (13:3, 13, 16; 23:76)

average utilization of 11.45 hours during 1976 (13:32, 86). Further, B-747 operating data published for the last quarter of 1976 indicated the five freighters possessed by Flying Tiger and Seaboard World achieved a cumulative daily average utilization of 10.96 hours (56:34). For illustration purposes, Boeing used an annual utilization of 4,000 hours (10.959 hours daily) when comparing the productivity of the B-747F and B-707-320 (8:60). Other examples of high utilization rates include Pan American's report of 12.6 hours per day for its B-747Fs operating the New York/Frankfurt route and the cumulative utilization

of 11.99 hours per day for B-747F North Atlantic cargo service during the period 19 April 1972 through 28 February 1974 (10:20; 11:Chart EG2265R5). Considering the past performance of all-cargo carriers and recent WB freighter operating data, an 11.5 hours per day utilization factor was selected based on Flying Tiger's performance rounded upwards. The annual ton-mile cargo aircraft productivity produced by the basic equation resulted in a constant conversion factor of 171,912,097.6 cargo ton-miles generated by one B-747 convertible or freighter aircraft per year.

GENERATION OF AIRCRAFT REQUIREMENTS

The main computer program was developed to permit variation of the anticipated aircraft mix required to service forecasted PRM and cargo ton-miles. Appendix I contains a computer flow diagram depicting the decision paths corresponding to the three situations examined. Each situation required the application of the basic equations derived to represent: (1) forecasted PRM, (2) forecasted cargo ton-miles, (3) passenger revenue mile aircraft productivity, (4) lower hold cargo ton-mile productivity, and (5) ton-mile cargo aircraft productivity. Collectively, the basic equations generated the number of WB and NB aircraft needed to service air traffic growth with incremental increases in deflated GNP of 0.5 percent for the span of the forecast period. In essence, the major difference between the three situations

rested with the percentage of revenue passenger traffic serviced by each type of passenger aircraft. Situations were varied by changing the percent of the market each group of aircraft would fly. The assumption that all convertible and freighter aircraft entering the system were wide-bodied was predicated on: (1) wide-bodied convertible and freighter aircraft provide favorable economies of scale, and (2) the average haul distance for domestic freight and express is projected to increase over the next decade (8:61; 42:53).[5] Overall, the computer model was designed to generate the number of passenger aircraft needed to service passenger requirements, the number of convertible aircraft needed to satisfy military strategic airlift requirements, and the number of freighter aircraft required to service residual air cargo requirements.

General

The log-linear regression equation produced by regressing PRM on deflated GNP provided the basis for forecasted PRM. In turn, PRM for varying levels of national economic growth were generated for the years 1976 through 1990 and a forecast envelope consisting of lower and upper limits at the 95% confidence level was established. Each forecast represented the expected PRM for the years

[5]Boeing's profitability analysis of a B-747F indicates that the aircraft "requires about the same payload to cover direct operating costs as two 707-320's [freighters], yet can provide 33 more tons of revenue cargo than the two 320's [8:61]."

1976 through 1990 for an average annual increase of 0.5 percent ranging from minus 1.0 percent to plus 6.0 percent (e.g., a total of 16 forecasts).[6] Consistent with the rationale outlined in this chapter relating to derivation of values contained in the equation for passenger revenue mile aircraft productivity, passenger aircraft in operation by the air carriers during 1976 were assumed to be underutilized (i.e., the actual combined load factor was 55.4 percent instead of the 60.0 percent load factor assumed to be a reasonable assessment of actual capacity which would have been utilized if a favorable economic situation prevailed). Since complete 1977 data was not available, a second assumption involved assuming aircraft in operation by the air carriers, including aircraft acquired in 1977, were fully utilized at the 60.0 percent Revenue Passenger Load Factor rate. In tandem, the two assumptions permitted calculation of aircraft required by air carriers beginning in 1978 by initializing forecasted PRM in 1978.[7]

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[6] In reality, the log-linear equation inserted in the main computer program generated an annual forecast for a given level of GNP. The high speed of the computer and use of looping permitted subsequent calculation of the number of passenger aircraft and other required computations prior to proceeding to the next annual forecast. Upon completion of the entire forecast for a given level of average economic growth, the program increased the growth rate by 0.5 percent.

[7] The ATA encountered a similar problem in compiling a fleet cost forecast for the U.S. airline industry. A passenger load factor of 60 percent was used for 1978 and beyond after gradually escalating the actual load factor with a ratio of previous years load factor to current year (1:10). The methodology employed by the ATA differs from the methodology employed in this thesis. Hence, the assumptions outlined above were made to achieve basically the same purpose as the ATA ratio.

Further, the 1978 annual forecast represented the first year a government sponsorship scheme could be undertaken.

Passenger, Convertible, and Freighter Aircraft

After forecasted PRM were generated by the model, the number of aircraft generated was dependent on the situation under consideration and the estimated percentage of short/medium NB and/or WB aircraft air carriers would purchase to service the anticipated growth in air traffic. Situation A posed the least complex situation where forecasted PRM were converted into B-747 passenger aircraft equivalents (i.e., air carriers were required to purchase only WB passenger, convertible, or freighter aircraft). The aircraft generated annually were then considered as available for delivery in a convertible configuration up to a cumulative maximum of 100 aircraft. In years where the lower hold capacity of the cumulative number of B-747C convertible aircraft failed to provide sufficient capacity to meet cargo forecasts, B-747F freighter aircraft were generated and the 100 convertible aircraft maximum reduced accordingly. When a combined total of 100 convertible and freighter aircraft was achieved, the model was allowed to continue generation of B-747 passenger and freighter aircraft until the end of the forecast period. The basic equations for the B-747B annual lower hold cargo productivity (see Table VI), PRM aircraft productivity (see Table III), and B-747F cargo

ton-mile conversion factor provided the links for translating forecasted PRM and cargo ton-miles into aircraft requirements.

Situation B increased the complexity of the model through the introduction of the possibility forecasted annual PRM would be serviced by a mix of B-727-200 and B-747B aircraft. Following a forecast of PRM for a given level of economic growth, a percentage of the PRM were translated into B-727-200 aircraft requirements with the remaining PRM converted into B-747 passenger or convertible aircraft procurements. As in the case of Situation A, a maximum total level of 100 B-747 convertible and/or freighter aircraft was established. Further, in years where the combined lower hold capacity of cumulative B-727-200 and B-747 convertible aircraft exceeded forecasted cargo ton-miles, new B-747F freighters were generated with a corresponding reduction in convertible aircraft. Upon achieving the 100 main deck cargo capable B-747 aircraft, the computer model was permitted to continue generating B-727-200, B-747B passenger, and B-747F freighter aircraft until the end of the forecast period. The basic equations used to derive the appropriate aircraft requirements in Situation A were also used for Situation B.

The final situation examined by the researchers resulted in introducing a higher degree of complexity. Specifically, Situation C represented the possibility of a short/medium range WB such as the A-300B4 or L-1011 capturing an increased share of air traffic.

Similar to Situation B, a percentage of forecasted PRM was allocated to each type aircraft. The same decision logic for achieving 100 main deck cargo capable B-747 aircraft as outlined for Situation B was applied to Situation C taking into consideration the passenger and lower hold cargo productivity of the short/medium range WB.

COST SENSITIVITY ANALYSIS OF PROGRAM COSTS

General

Depending on the level of real national economic growth, situation under examination, and corresponding time-phased flow of aircraft, government sponsorship costs in current year dollars for each year of activity were determined. Since cash flows for each year were not expected to remain constant due to a variation in anticipated investment and operating costs as well as air carrier reimbursements, the computer model was designed to render total program costs on a comparable basis. Through the use of discount factors reflecting uniform cash flows throughout each program year, the present value of the total cost associated with each time-phased flow of aircraft was calculated based on an economic life of 13 years (1978 through 1990).

The discount rate policy used by the Air Force prescribes a discount rate of 10 percent which represents "an estimate of the average rate of return on private investment before corporate taxes and after adjusting for inflation [75:11]." Since there is no stated

government policy on inflation (76:18), the main computer program economically adjusted all costs and projected reimbursements by a 6 percent inflation rate. Appendix K outlines the discount factors used for each program year. The use of the present value technique was restricted to only those situations in which 100 cargo capable aircraft were generated over the economic life of the program. Therefore, the situation which exhibited the least present value cost was considered the most desirable (76:15).

The very nature of the uncertainty involved in economic forecasting precluded measurement of one single time-phased flow of aircraft that could be expected during the life of a program designed to provide 100 cargo capable aircraft. Consequently, the use of cost sensitivity analysis provided the means for determining the range of total costs associated with each given situation.

The annual cash flows considered in the analysis were limited to: (1) initial government sponsorship of the cost differential between a B-747 passenger and convertible aircraft, (2) government sponsorship of additional operating costs attributable to increased operating empty weight (OEW) of a convertible aircraft, and (3) reimbursements made by airlines on a per cargo ton-mile basis up to the initial investment cost sponsored by the government.

Investment Costs

Total program investment costs were represented by the economically escalated difference in cost between a B-747 passenger and convertible aircraft. The initial program year (1978) cost was derived by inflating the cost difference outlined by Pugh (60) in his comprehensive study of the B-747 convertible. An estimate of $5.848 million per aircraft for the initial program year was calculated by: (1) using the Wholesale Price Index for Transportation Equipment to adjust the 1973 cost difference to 1 July 1977 constant dollars, and (2) adjustment for a 6 percent annual inflation rate until the beginning of the program on 1 January 1978.[8] The average annual cost per aircraft was based on a mid-year price.

The main computer program escalated the unit and annual aggregated investment cost by a 6 percent average annual inflation rate and provided the cost in terms of current year dollars. The convertible aircraft's cost difference as depicted in the computer output for each year was predicated on two major assumptions; namely, (1) inflation would remain constant at 6 percent, and (2) no change in

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[8]After an appropriate index series has been selected, the approach is to deflate (or inflate) the actual price paid previously to a base year and then inflate (or deflate) the actual price (19:31-34). In this case, the 1973 cost difference was stated as $4.1 million. The Wholesale Price Indices for 1973 and June 1976 were 115.1 and 159.4, respectively (16:408; 17:2). When $4.1 million is divided by 1.151 and then multiplied by 1.594, the resultant amount is $5.678 million, which when increased by 3 percent, yields $5.848.

the real price of the convertible would occur. The second assumption presupposed a static pricing policy of the aircraft manufacturer regardless of supply or demand. In other words, an increased demand for aircraft to service requirements was assumed to have no effect on supply and price. Any unusual disturbances in the pricing policy of the aircraft manufacturer could seriously impair forecasted program costs; however, if a change in pricing policy was applied to all models by the manufacturer proportionately, the model would not necessarily be affected. Further, there is the likelihood that large procurements of a convertible aircraft would result in a substantial reduction in cost by as much as 29 percent for orders over 50 aircraft (3:34).

Operating Costs

The difference between the operating empty weight (OEW) of B-747-200B passenger and B-747-200C convertible aircraft is 12,000 pounds; however, the added structural strength provides the airline with an additional 51,000 pounds at the zero fuel limit of lift capacity (see Appendix L). Recurring annual operating costs were computed based on an OEW penalty of 12,000 pounds as a ratio of the combined OEW and average ton payload exhibited by air carriers. Block hour costs covering airline direct operating expenses (less insurance and writeoffs) were multiplied by the ratio to yield a direct operating cost

attributable to transporting the OEW on a fleet-wide basis. The ton-miles flown with respect to OEW were determined by multiplying the average aircraft OEW by total distance flown by the fleet (i.e., number of departures multiplied by average hop length equaled distance flown). Cost of OEW per ton-mile was attained by division of OEW ton-miles into the applicable portion of direct operating cost.

Average operating expenses attributable to an additional OEW of 12,000 pounds per year per aircraft was depicted in the computer model by the equation,

$$\begin{array}{l}\text{6 Tons}\\ \text{Operating}\\ \text{Empty}\\ \text{Weight}\\ \text{(OEW)}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Airborne}\\ \text{Speed}\end{array} \times \begin{array}{l}\text{Average}\\ \text{Daily}\\ \text{Utilization}\end{array} \times \begin{array}{l}\text{Cost per}\\ \text{Ton-mile}\\ \text{OEW}\end{array} \times 365$$

$$= \begin{array}{l}\text{Annual Operating Cost Attributable}\\ \text{to Additional OEW.}\end{array}$$

Consistent with the equation for PRM aircraft productivity, average airborne speed and average daily utilization remained as outlined in Table III. Cost per ton-mile OEW, however, was derived by using a weighted average of the block hour costs associated with the April 1976 through March 1977 operations of two airlines, United and Trans World. The rationale for selection was predicated primarily on similarity of aircraft equipment (all operated B-747-100 passenger aircraft). Figure 7 illustrates the block hour costs for various air

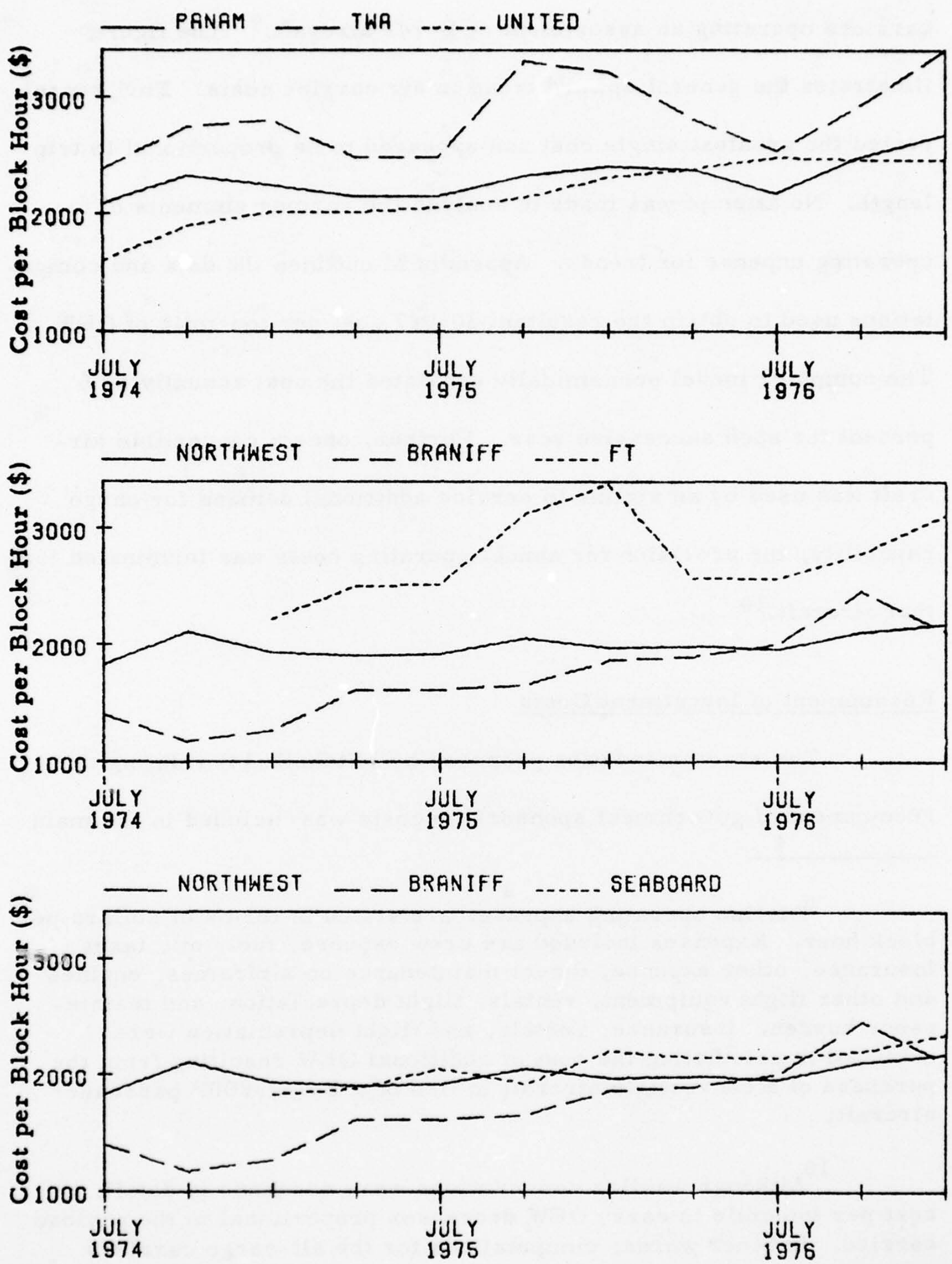

Fig. 7. Average Quarterly Block Hour Costs for Selected Air Carriers, Operating B-747 Aircraft

Source: Various Issues of Aviation Week and Space Technology

carriers operating an assortment of B-747 aircraft.[9] The figure illustrates the general upward trend in air carrier costs. Fuel represented the greatest single cost and appeared to be proportional to trip length. No attempt was made to analyze the various elements of operating expense for trends. Appendix M outlines the data and computations used to obtain the resultant $0.027 cost per ton-mile of OEW. The computer model economically escalated the cost annually by 6 percent for each successive year. Further, once a convertible aircraft was used by an airline to service additional demand for cargo capability, the provision for annual operating costs was terminated for that aircraft.[10]

Recoupment of Investment Costs

The recommendation proposed by Mitchell (14) relating to recoupment of government sponsorship costs was included in the main

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[9] Airline operating expenses are stated in terms of dollars per block hour. Expenses included are crew expense, fuel, oil, taxes, insurance, other expense, direct maintenance on airframes, engines and other flight equipment, rentals, flight depreciation, and maintenance burden. Insurance, rentals, and flight depreciation were excluded in calculating the cost of additional OEW resulting from the purchase of a convertible aircraft in lieu of a B-747-200B passenger aircraft.

[10] Although similar computations were not made in detail, the cost per ton-mile to carry OEW decreases proportional to the payload carried. In other words, computations for the all-cargo carriers operating strictly freighters would yield a per ton-mile cost considerably less than that of passenger aircraft. Hence, the reason for using airlines with only passenger aircraft.

program by the introduction of a revenue per cargo ton-mile factor. Each convertible aircraft generated as the result of a specific level of economic growth was considered to have a potential annual productivity of 171,912,097.6 ton-miles per year. The potential, however, was dormant until the combined passenger aircraft lower hold cargo capability and freighter aircraft cargo capability became fully utilized within the context of the basic equations. At that time, on an annual basis, convertible aircraft were considered as being placed in service to meet the additional demand for cargo capability. The total ton-miles of cargo capability used was then multiplied by a percentage of the gross revenue yield per cargo ton-mile estimated for the year in which the capability was utilized. The resultant dollar amount was deducted from the total annual budget cost to yield a net budget required to meet continued investment and operating costs as applicable.

The base year (1978) gross revenue yield per cargo ton-mile was estimated at $0.278 and economically escalated at an average annual 6 percent inflation rate for each successive year. Three basic considerations impacted on the selection of a base year estimate as follows: (1) the 1977 Boeing estimate of gross revenue yield used in marketing literature for promotion of the B-747 Combi aircraft, (2) average gross revenue yield experienced by the CRAC in 1976, and (3) average gross revenue yield achieved separately by trunk and all-cargo carriers in 1976. Table VII provides a summary of the

calculated gross revenue yields for selected segments of the CRAC and the Boeing estimate which was subsequently used in the computer model.

Table VII
Gross Revenue Yield per Cargo Ton-mile
(2:42-43; 12:12; 13:1-3)

Carrier(s) or Manufacturer (1)	1976 Freight/Express Ton-miles Flown (000) (2)	1976 Operating Revenue (in Thousands of Dollars) (3)	Gross Yield per Ton-mile (dollars) (4)
Total CRAC Scheduled Service	5,096,178	1,482,491	0.2909
Trunk Carriers Scheduled Service	3,752,341	1,102,907	0.2939
All-cargo Carriers Scheduled Service	1,240,669	285,105	0.2298
Boeing 1977 Estimate	n/a	n/a	0.2780

The use of a 6 percent average annual increase in gross revenue yield was considered conservative since an understatement of recoupment would not decrease total program costs. In 1975 and 1976, there were 10 to 12 percent increases to stem underpricing of air cargo. The forecast for 1977 is 10-12 percent increase in rates

with a shift away from trunk carriers due to an increasing shortage of short and medium haul capacity (62:24-26).

Air carrier reimbursement on a per cargo ton-mile basis was set arbitrarily at a rate of 0.5 percent of gross revenue yield. Although the rate may seem exceedingly small, a hypothetical situation with actual data illustrates the impact on net profit. If, for example, all of Flying Tiger's aircraft were government sponsored convertibles that had been transitioned to a freighter mode, the airline's net profit would be decreased by 5.0 percent when reimbursement is made at the 0.5 percent rate. Specifically, a review of 1976 operating expense and revenue data for Flying Tiger reveals revenue for scheduled freight and mail was $208.1 million for 873.7 million cargo ton-miles. This equates to $1.04 million of reimbursement. Further, the proportion of profit attributed to scheduled freight and mail was $20.7 million. Therefore, reimbursements as an out-of-pocket expense would have a dollar for dollar reduction on net profit before taxes, or the equivalent to a 5.0 percent decrease in net profit (13:32; 2:42-43).

CHAPTER IV

RESULTS AND VALIDATION

The dynamic growth of U.S. commercial airlines since World War II has resulted from improved technology and an associated increase in the demand for air carrier services. Similar to numerous service oriented industries, airline growth has closely paralleled U.S. economic growth reflected by the GNP. The means by which air carriers service demand for air transportation is the product of the operating characteristics of the aircraft mix they select in an effort to minimize operating costs and maximize efficiency. In turn, the aircraft mix selected by air carriers has a direct impact on the amount of strategic airlift capability available to meet emergency contingency and wartime operations. Specifically, aircraft entering the U.S. civil air fleet are evaluated as to their utility in supporting airlift requirements based on Joint Chiefs of Staff (JCS) approved contingency plans. Following a determination of aircraft suitability by MAC, the Director, OET then allocates aircraft to the CRAF program (71:2—2-2—3). As an integral part of the National Strategic Airlift Resource, the CRAF is, in the last analysis, the result of

many factors bearing on the decisions made by U.S. air carriers as to the aircraft mix suited for servicing various market segments.

In an effort to determine the economic feasibility of a government sponsored convertible aircraft, the researchers constructed a computer model to examine the interrelationship of aircraft equipment decisions made by air carriers, varying levels of national growth, and the net discounted program costs of introducing 100 WB cargo capable aircraft into the air carrier fleet. The use of a computer model permitted flexibility and rapid processing of changed input parameters to observe the impact of varying levels of deflated (real) economic growth, equipment policies of air carriers, and program costs. Further, the computer model examined the associated time intervals required to attain the program goal of 100 WB cargo capable aircraft. Lastly, as a result of a recommendation advanced by Mitchell (39), the model incorporated an analysis of the impact of reimbursements made by air carriers whenever a government sponsored convertible aircraft was transitioned to the freighter mode by an air carrier.

In general, construction of the computer model proceeded in five phases. Phases I and II involved forecasting air passenger and air cargo market activity for varying levels of U.S. economic growth. Phases III, IV, and V encompassed derivation of basic equations (see Chapter III) depicting aircraft productivity, construction of the actual

model, and translation of market activity into program costs. This chapter outlines sequentially an analysis of the results and observations noted by the researchers.

AIRLINE MARKET FORECAST

Through the use of methodology employed by Rand Corporation in 1972 to forecast energy consumption relative to freight transport, future airline activity was determined for incremental increases in deflated GNP based on historical airline and GNP data. Appendices C through F provide detailed data on air passenger, cargo, and mail movements during the period 1950 through 1976. The data was subsequently aggregated for use as a computer data base (see Appendix G). GNP data for a similar time period is outlined in Appendix H. Graphically, Figure 8 highlights the impressive growth of airline traffic following World War II. Although the average growth rate of air freight exceeded 11.0 percent for the period 1950-1974, there had been a continued decline since the growth rate reached a peak of over 19.0 percent between 1960 to 1965. During 1970 to 1974, the growth rate was just over 6.0 percent (42:5).

The Regression Model

The Rand study regressed air cargo ton-miles on deflated GNP to determine the growth trend of airfreight for the periods 1939

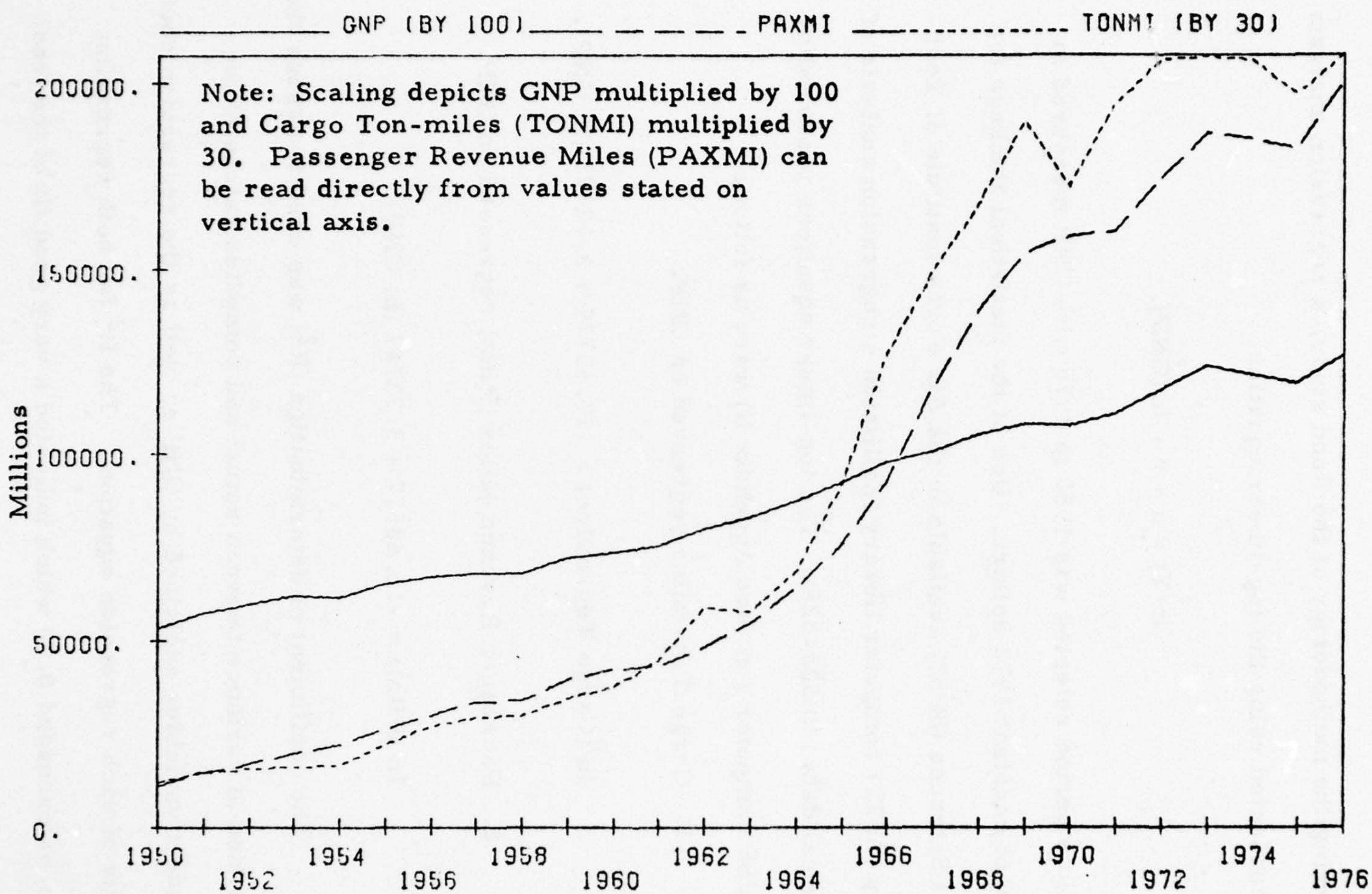

Fig. 8. Plots of Historical Data for GNP (1972 = 100), Passenger Revenue Miles, and Cargo Ton-miles (1950-1976)

to 1968 and 1947 to 1968. GNP was measured in billions of 1947 dollars and air cargo volume in millions of ton-miles (68:11-12). Following the methodology of the Rand study, a regression analysis was conducted using the log-linear equation,

$$\ln(Y) = a + b \cdot \ln(GNP).$$

The time period selected was 1950 to 1976 with GNP measured in terms of constant 1972 dollars. Use of the Statistical Package for Social Sciences (SPSS) available in the Air Force Institute of Technology (AFIT) computer library facilitated a regression analysis of historical data (40:323-328). The log-linear equations produced by the SPSS computer run (see Appendix N) were as follows:

1. Cargo Ton-miles regressed on GNP.

$$\ln(\text{Cargo Ton-miles}) = -17.45739 + 3.72425 (\ln GNP).$$

2. Passenger Revenue Miles (PRM) regressed on GNP.

$$\ln(PRM) = -11.48577 + 3.33747 (\ln GNP).$$

The coefficient of determination (R^2) was used to assess the proportion of variance between actual and computed values of the dependent variables explained by GNP as well as the regression coefficients of each regression equation. The R^2 for both regression equations exceeded 0.99 which indicated a very good fit of the least

squares log-linear regression line to the data. Figures 9 and 10 illustrate the log-linear regression lines for cargo ton-miles and PRM, respectively. The regression coefficient (b) was tested and found significantly different from zero at the 99.9% confidence level. Thus, the conclusion was made that the variables, GNP and cargo ton-miles, and GNP and PRM, were not independent. Regression results and hypothesis tests performed to verify statistical significance are outlined in Appendix O.

Market Forecast

The log-linear equations derived through regression analysis were input to the main computer model to generate annual forecasts for incremental 0.5 percent increases in deflated GNP. Appendix P outlines the computer program and market forecasts initialized on the 1976 deflated GNP value of $1264.7 billion. Forecasts for both cargo ton-miles and PRM were enveloped by upper and lower confidence limits at the 95.0 percent level (24:540). Figures 11 and 12 illustrate forecasted growth of cargo ton-miles and PRM for 1976 through 1990 based on sustained average annual GNP growth rates ranging from minus 1.0 percent to 6.0 percent. The steepness of the curves prevalent during the latter years of each forecast is the result of using a log-linear equation to extrapolate into the future. Although the forecasts above a 4.0 percent GNP growth rapidly increase at an

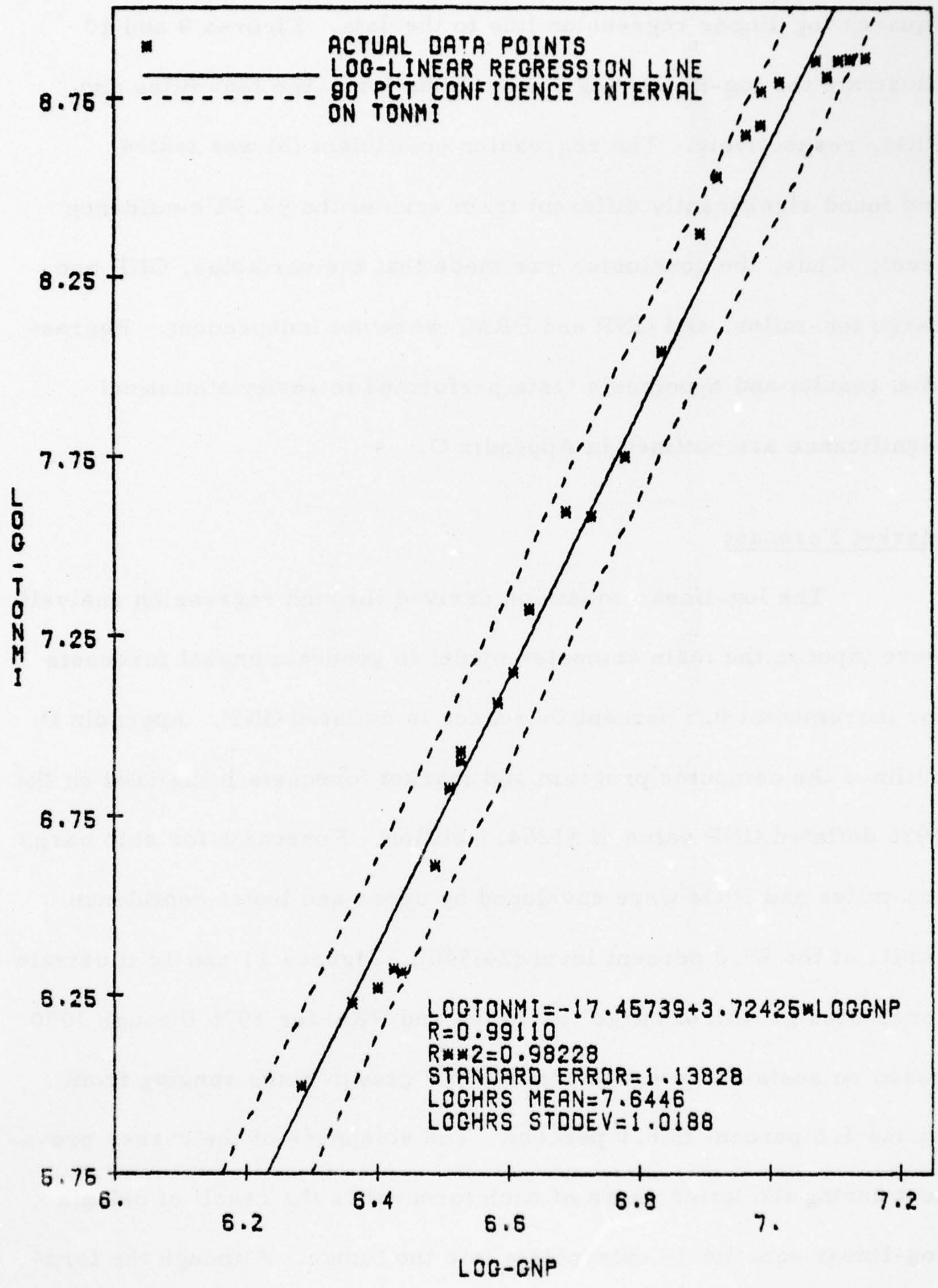

Fig. 9. Log-linear Regression Line for Cargo Ton-miles

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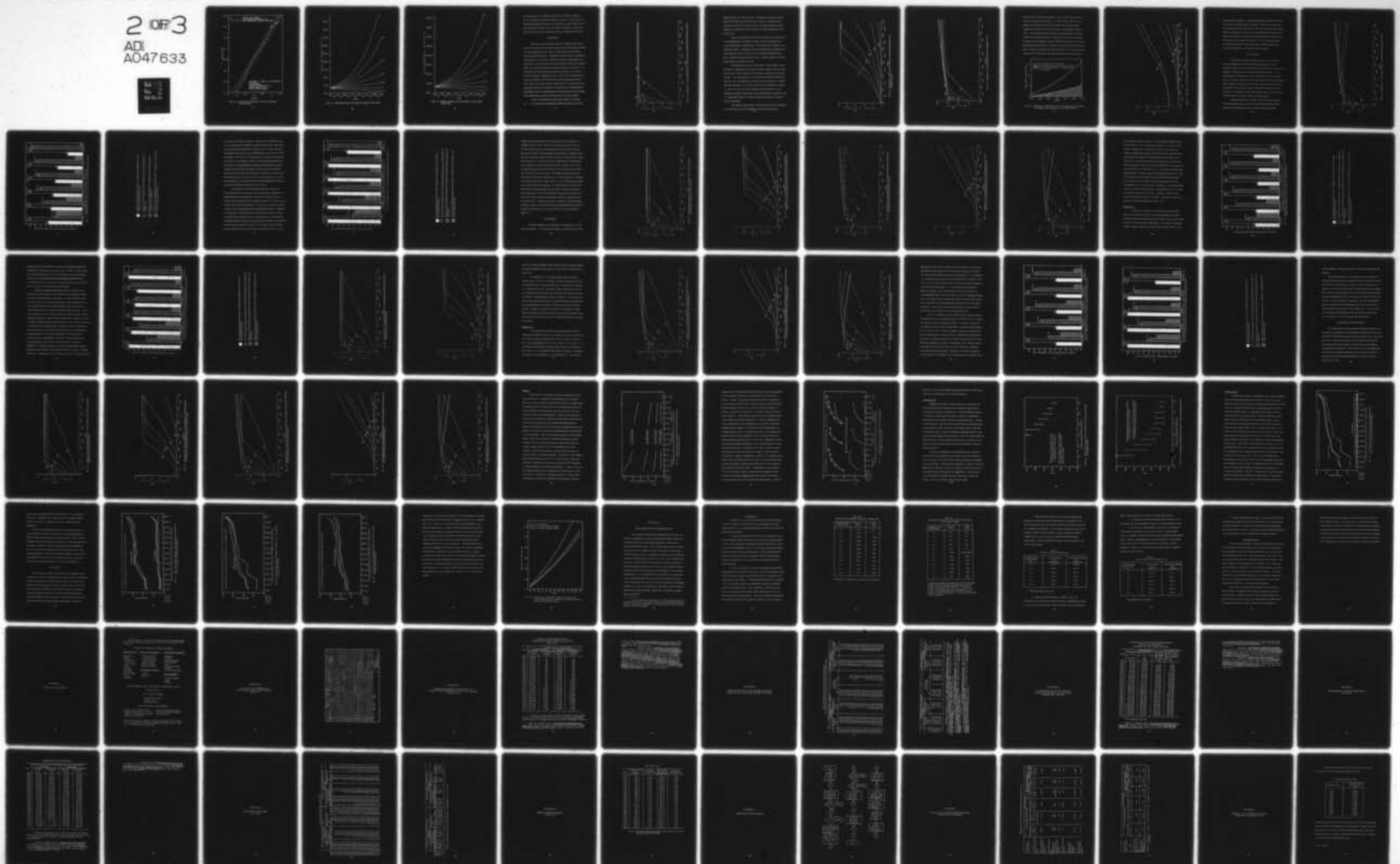

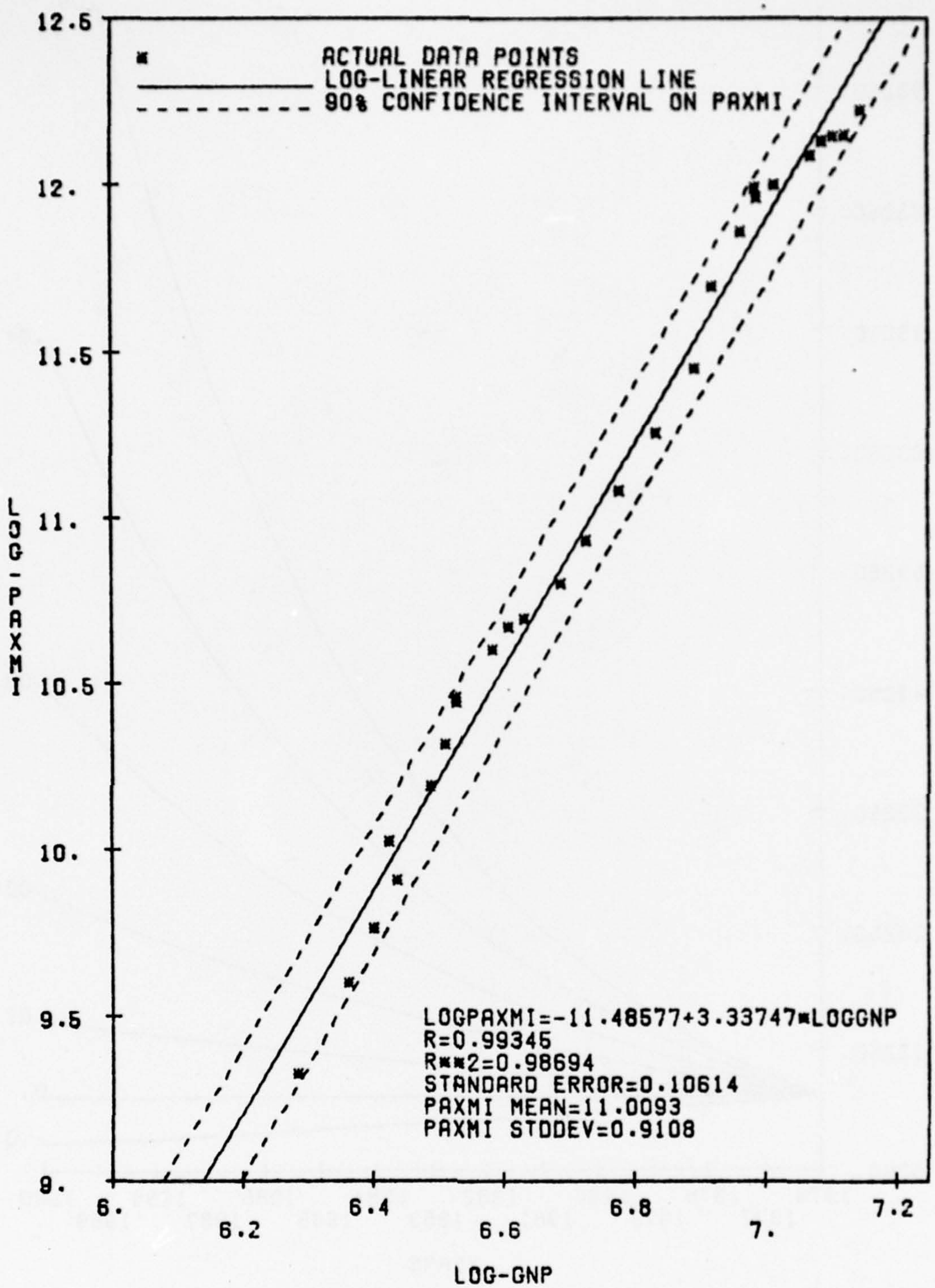

Fig. 10. Log-linear Regression Line for Passenger Revenue Miles

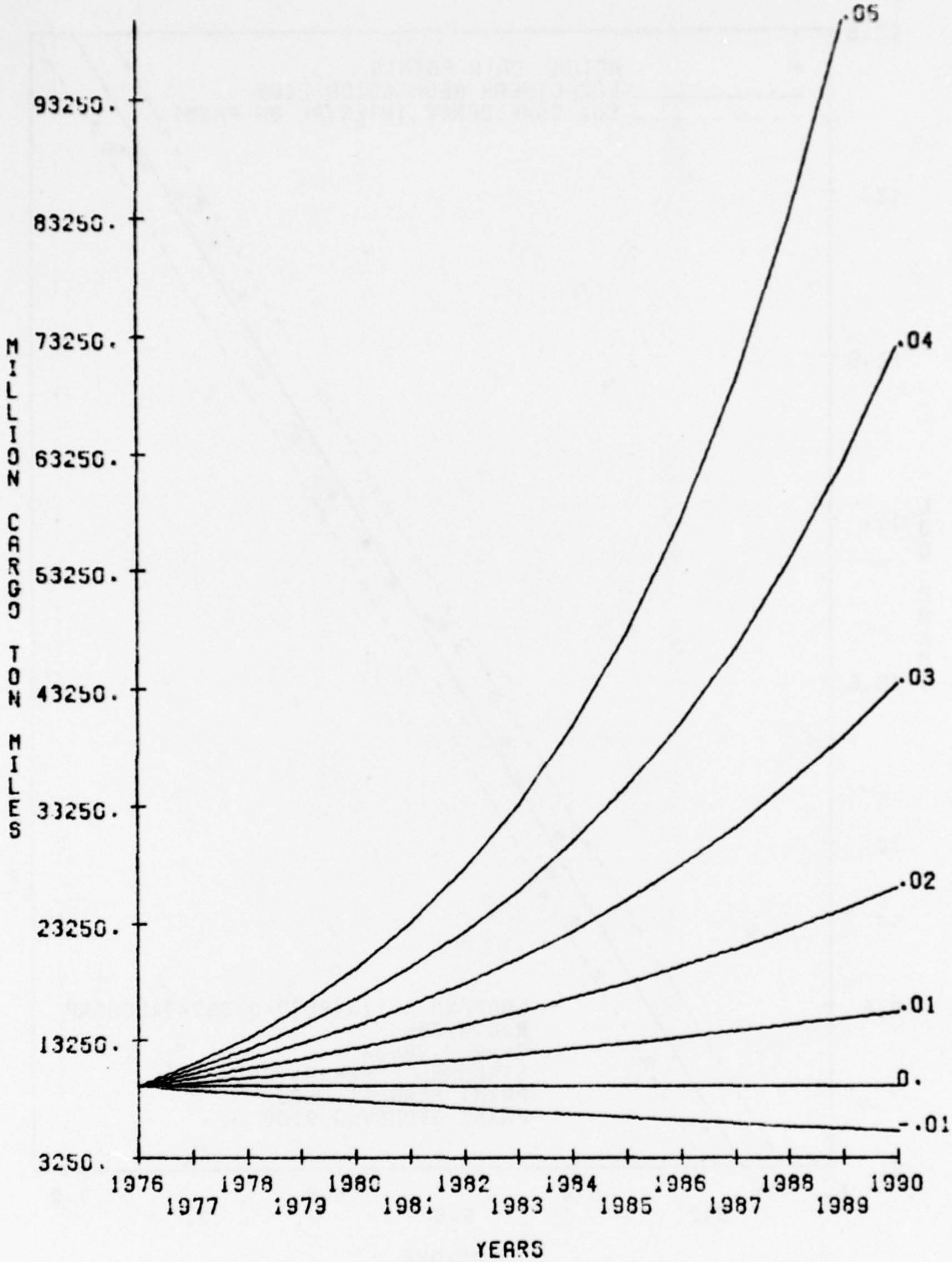

Fig. 11. Market Forecast for Cargo Ton-miles (1976-1990)

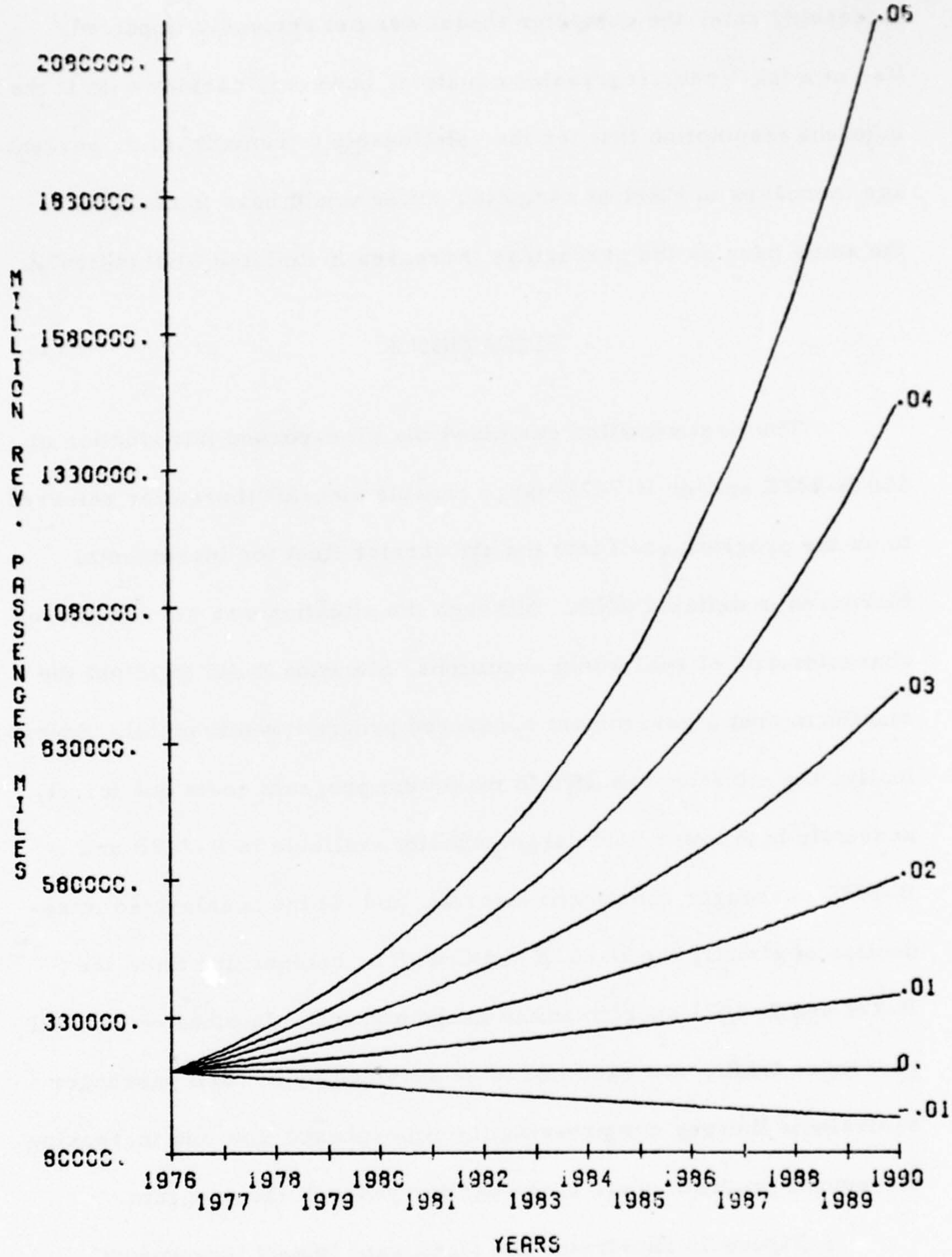

Fig. 12. Market Forecast for Passenger Revenue Miles (1976-1990)

increasing rate, the computer model was not seriously impaired. Use of a log-linear regression equation, however, carries with it the inherent assumption that for the relationship to remain valid, percentage increases in PRM or cargo ton-miles would have to continue at the same pace as the percentage increases in deflated GNP (64:647).

SITUATION A

The first situation examined the time-phased introduction of 100 B-747C and/or B-747F cargo capable aircraft (hereafter referred to as the program goal) into the air carrier fleet for incremental increases in deflated GNP. Although the situation was not considered characteristic of real world conditions, Situation A did highlight the maximum cost a government sponsored program would entail. Specifically, the situation resulted in maximum program costs due to: (1) unusually high lower hold cargo capacity available in B-747B and B-747C passenger configured aircraft, and (2) the accelerated introduction of strictly the B-747B and C with no competition from the B-727 and L-1011 short/medium range aircraft. In other words, all passenger traffic was assumed to be serviced by B-747B passenger equivalents thereby compressing the time-phased flow and increasing discounted program costs in the earlier years of the program.

Figure 13 illustrates the significant impact incremental increases in sustained average annual GNP growth had on the time

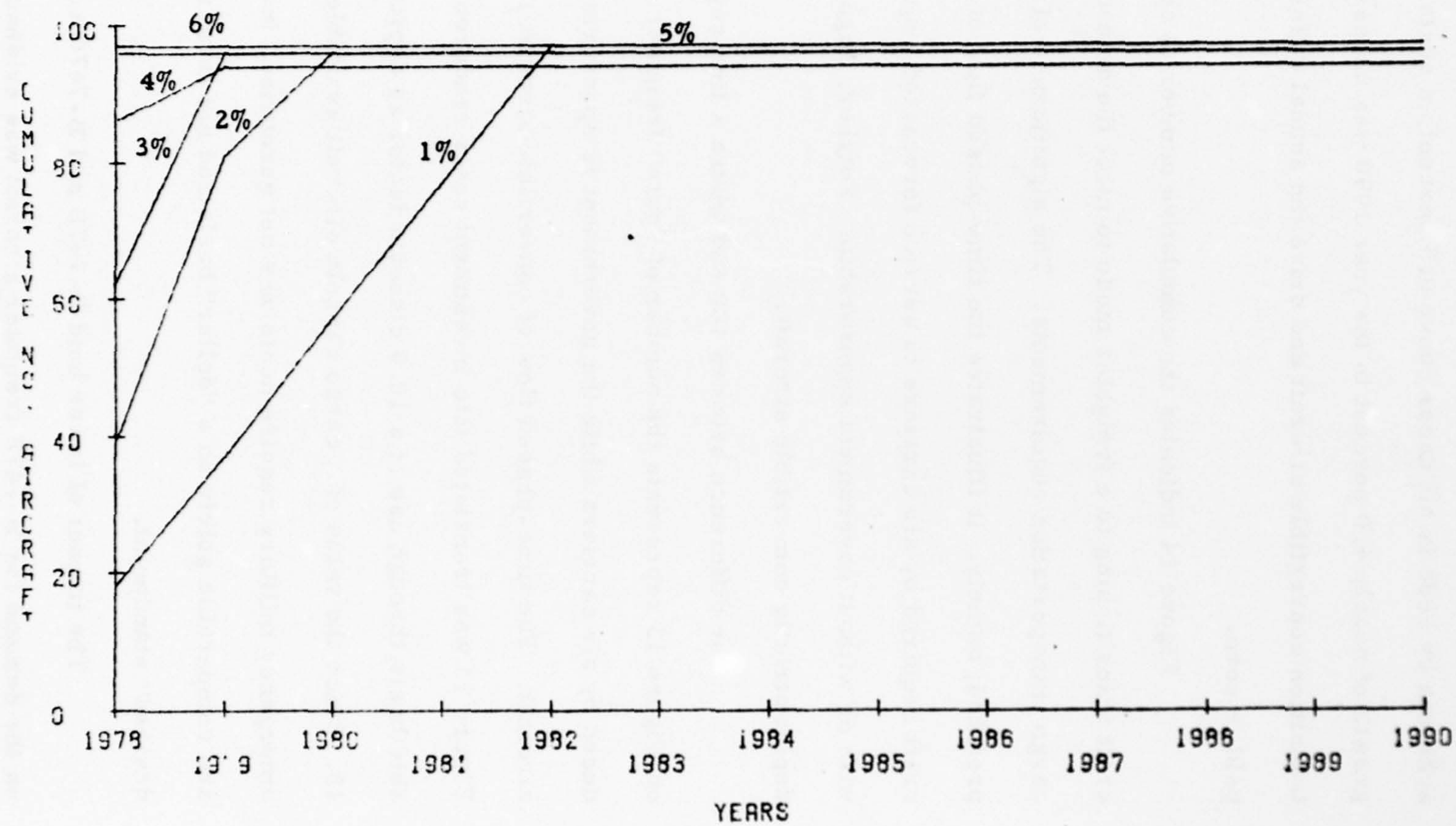

Fig. 13. *Situation A: Time-phased Flow of Government Sponsored Convertible Aircraft*

phased flow of convertible aircraft. Although the program goal was achieved by 1988 in all cases above 0.5 percent, a sustained GNP growth of nearly 4.0 percent to the year 1990 was necessary to fully transition convertible aircraft and drive the annual differential cost paid to zero.

Figure 14 indicates the cumulative number of convertible aircraft transitioning to a freighter mode to meet the demand for air cargo transportation requirements. The significance of Figure 14 is profound; namely, it illustrates the time-phased flow of freighter aircraft required by air carriers to service forecasted requirements with or without government sponsorship. Further, Figures 13 and 14 depict strictly convertible aircraft.

The difference between 100 and where a line segment ceases on Figure 13 represents the number of "pure" freighter aircraft introduced by air carriers while the government is sponsoring convertible aircraft. The time-phased flow of convertible aircraft illustrated in Figure 13 was translated into investment costs rendered on a comparable basis through use of a 10.0 discount factor as depicted in Figure 15. Since the value of a cargo capable aircraft available to meet emergency military requirements was not quantified, investment costs are comparable solely on a "dollar" basis and not from a "benefits derived" standpoint.

The impact of lower hold B-747B and B-747C cargo capability on the demand for B-747F freighter aircraft was evidenced by

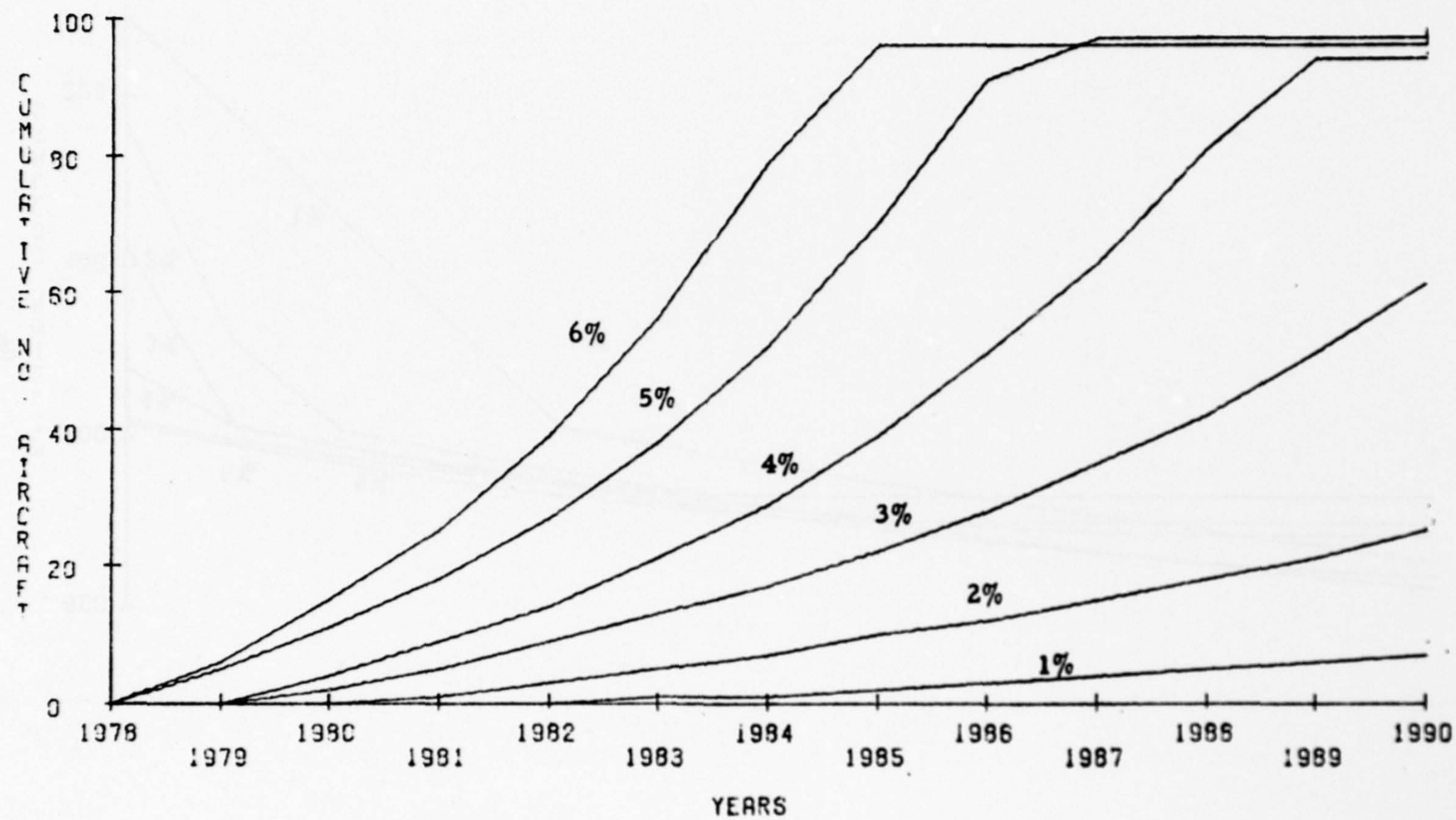

Fig. 14. Situation A: Time-phased Flow of Convertible Aircraft to a Freighter Mode

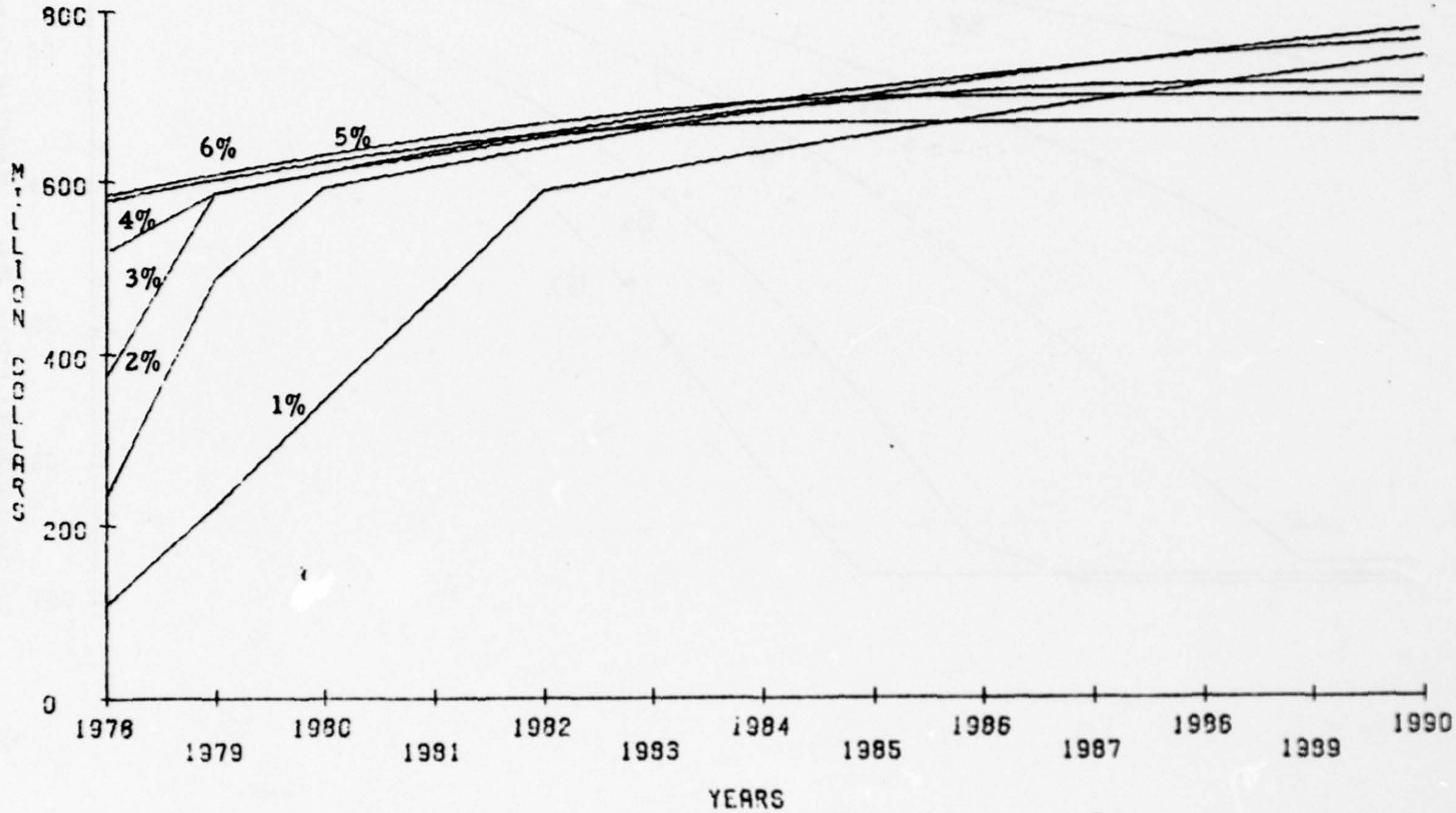

Fig. 15. Situation A: Time-phased Flow of Program Costs

the relative few number of freighters and/or convertible aircraft flown in a freighter mode under a 3.0 GNP growth. However, at a healthy 4.0 percent GNP average growth level, all government sponsored convertibles were transitioned to the freighter mode by 1989. The interrelationship of the lower hold capability of a large number of passenger aircraft B-747B and B-747C aircraft and the purchase of pure freighters is fully illustrated by Figure 16 at a 2.0 percent GNP growth level. In terms of a government sponsored program, Figure 17 highlights the depressing effect of lower hold cargo utilization on anticipated reimbursement from convertible aircraft

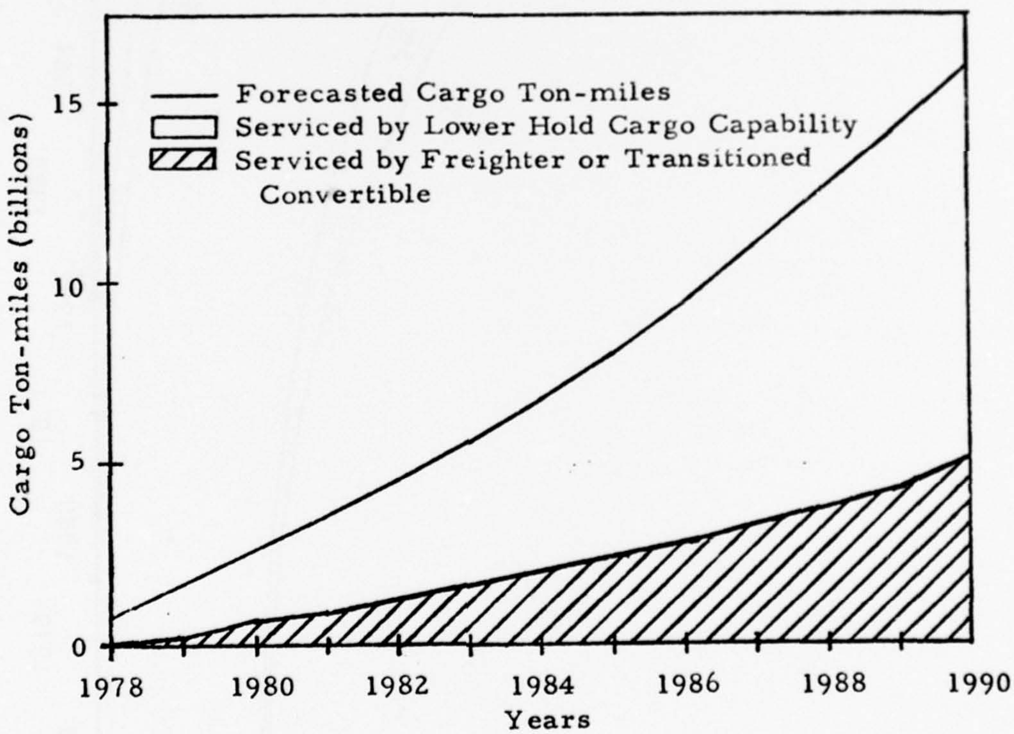

Fig. 16. Situation A: The Impact of Lower Hold Cargo Capability on Freighter Procurement at a 2.0 GNP Growth

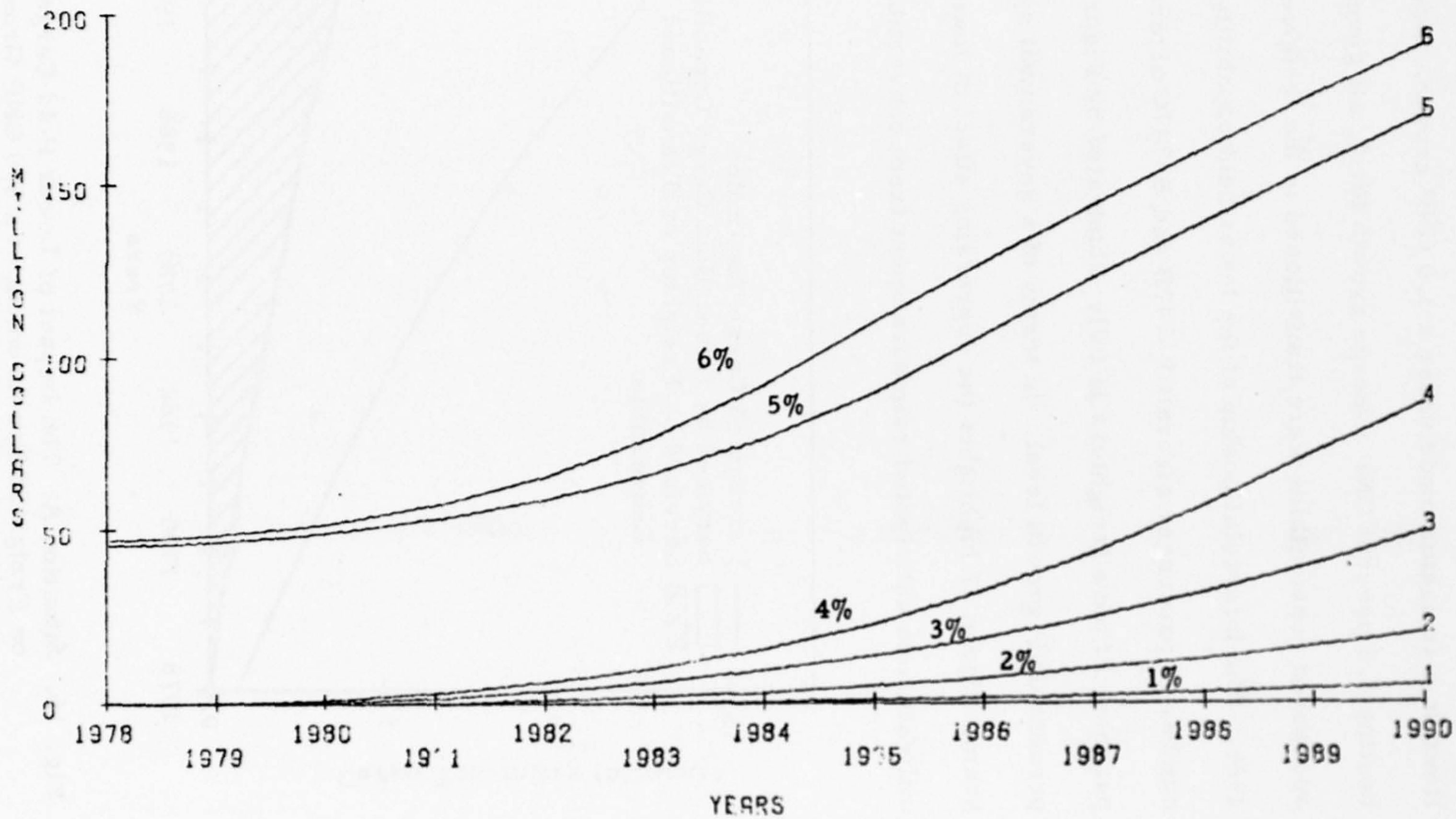

Fig. 17. Situation A: Time-phased Flow of Discounted Air Carrier Reimbursements

transitioned to freighters. Reimbursement was computed at 0.5 percent of gross revenue yield per ton-mile. Clearly, at no point are investment costs fully recouped over the economic life of the program. Figure 18 provides an overall view of cumulative discounted net program costs taking into consideration reimbursements (see Figure 17) for each level of average annual growth. At a 1.5 percent growth, net discounted program costs reach a high of $758.0 million and decrease rapidly after a 3.0 growth rate is achieved.

SITUATION B

The situation examined under Situation A was unrealistic from the standpoint of present technology and decision criteria employed by air carriers in selecting aircraft to service their market segment. Excluding the 6.9 percent of PRM serviced by L-1011 short/medium WB aircraft in 1976, B-747 and DC-10 WB aircraft flew 29.9 percent of all PRM (53:32-33; 54:40-41; 55:36-37; 56:34-35). The remainder was flown by NB aircraft. Situation B increased the complexity of the computer model to permit an examination of the impact of an increased (or decreased) market share of PRM flown by B-747B aircraft in relation to the B-727 NB aircraft.

Figure 19 provides a summary of gross and net program costs associated with a 2.0 percent average annual deflated GNP growth and varying levels of the air traffic passenger market

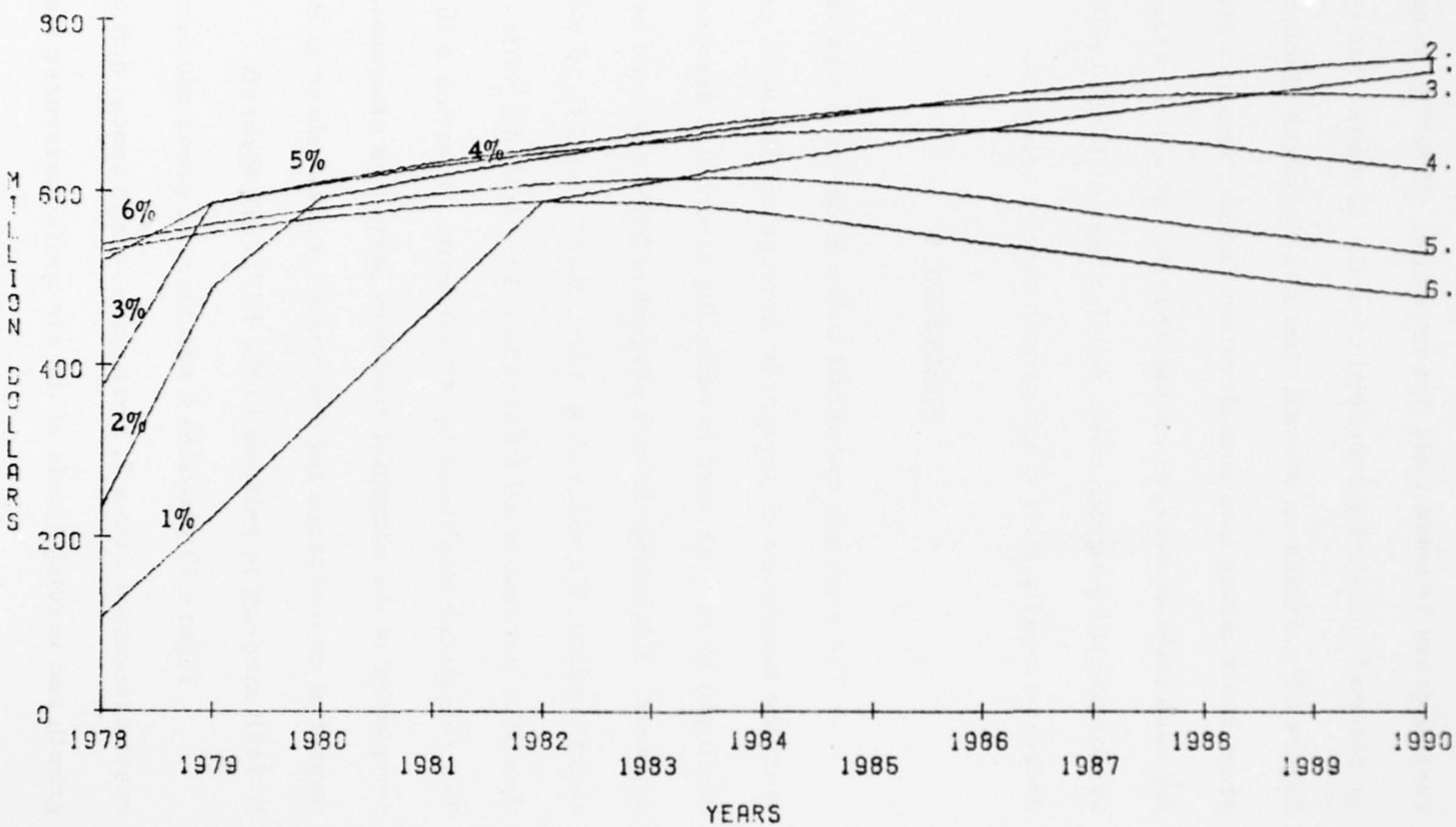

Fig. 18. Situation A: Time-phased Flow of Discounted Net Program Costs

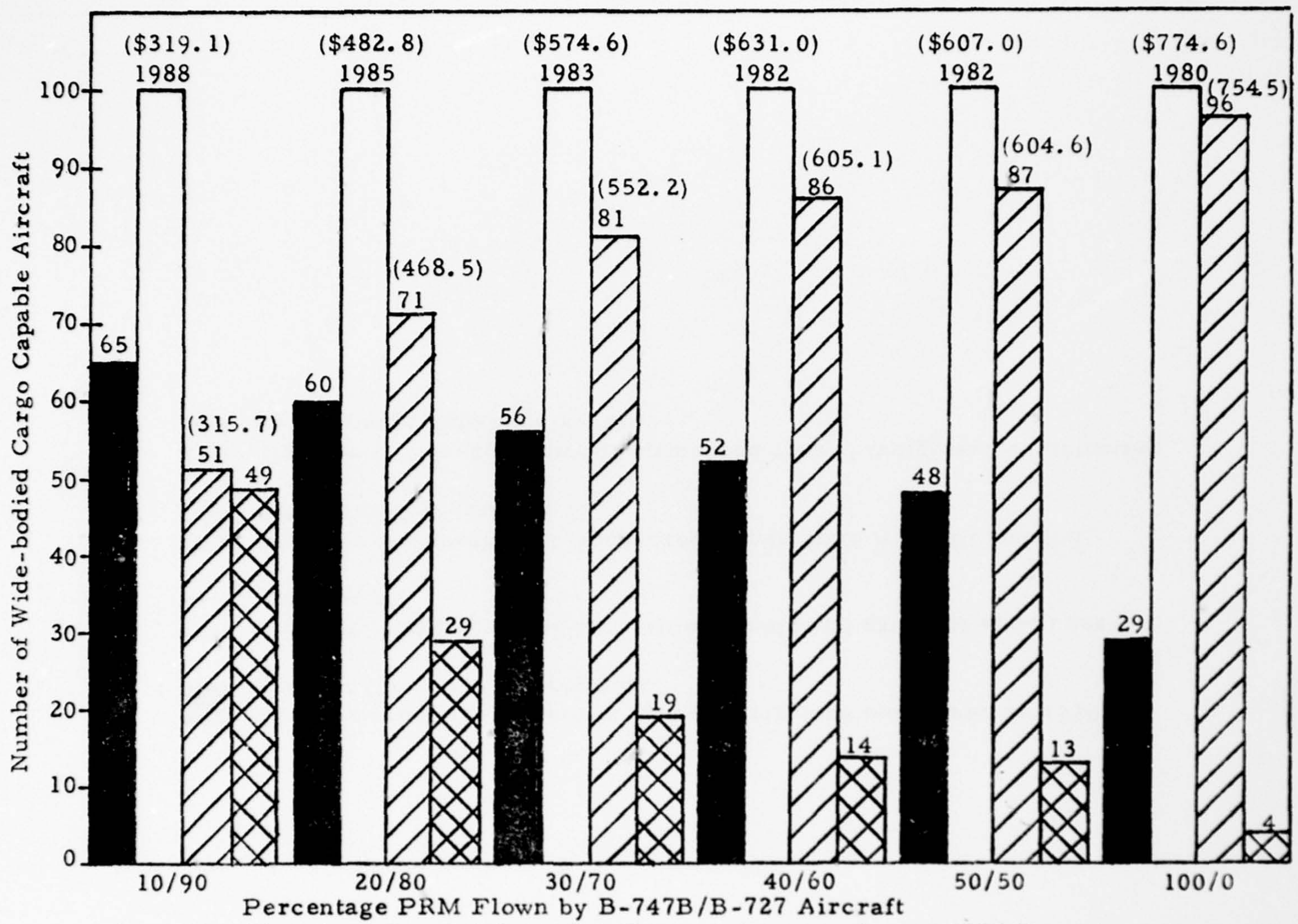

Fig. 19. Situations B and A for a 2.0 Percent Average Annual GNP Growth

- ■ Non-government-sponsored "pure" freighters purchased by 1990 without Government Program.
- □ Year 100 cargo capable aircraft available and gross program cost (million $).
- ▨ Number of Government-sponsored Convertible Aircraft and Net Program Cost (million $).
- ⊠ Number of Non-government-sponsored "pure" freighters contributing to 100 cargo capable aircraft.

serviced by both types of aircraft. Situation A was included to provide a comparison and maintain continuity of the model. The significant relationships highlighted by Figure 19 are: (1) both gross and net program costs increase as the PRM market share of the B-747B increases, (2) the earlier the program goal is achieved, the greater the cost due to the earlier investment costs discounted heavier than later costs, (3) approximately 50 percent of the desired 100 cargo capable aircraft would be available by 1990 without a government sponsored program given NB aircraft fly a minimum of 50 percent of the PRM market, and (4) the reduced lower hold capacity of NB aircraft promotes a 7.0 percent increase in WB freighters for each 10.0 percent of the PRM market flown by NB aircraft.

The inability of the NB passenger aircraft to cope with increased demand for air cargo service is depicted in Figure 20. As deflated GNP growth approaches 3.0 percent, program costs are reduced and the program goal is achieved between 1 to 4 years earlier. Further, the model indicated that by 1990 the goal would be achieved whether or not a government sponsored program existed. A comparison of figures 19 and 20 illustrates the significant impact a 3.0 percent GNP growth would have on air cargo operations. Although the time-phased flow of aircraft is accelerated, the number of convertible aircraft remain relatively constant. In the middle 1980s, however, market pressure for air cargo service generates the need for cargo

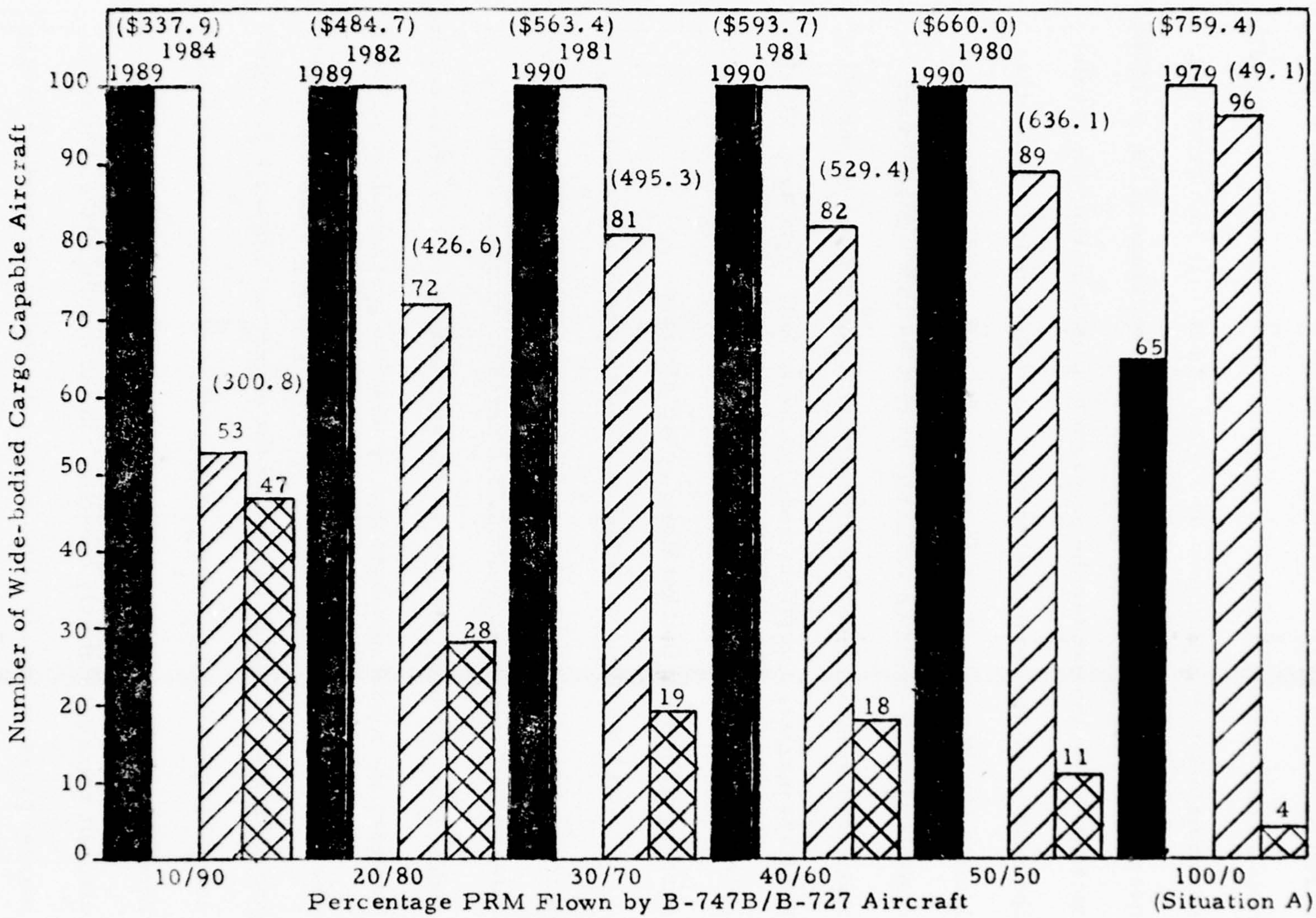

Fig. 20. Situation B for a 3.0 Percent Average Annual GNP Growth

■ Non-government-sponsored "pure" freighters purchased by 1990 without Government Program.

□ Year 100 cargo capable aircraft available and gross program cost (million $).

Number of Government-sponsored Convertible Aircraft and Net Program Cost (million $).

Number of Non-government-sponsored "pure" freighters contributing to 100 cargo capable aircraft.

capable aircraft and results in rapid transition of convertibles to a freighter mode by 1990. Figures 21 and 22 provide an overview of the time-phased flow of government sponsored convertible aircraft entering the system and subsequently transitioned to a freighter mode when 30.0 percent of annual PRM are flown by B-747B aircraft. With the exception of a .5 percent increase in GNP growth, sufficient WB cargo capable aircraft are phased in by 1990. Figures 23, 24, and 25 illustrate discounted cash flows when 30.0 percent of annual PRM are serviced by B-747B aircraft. The highest cumulative program cost of $574.6 million was attained at a 2.0 percent growth. Program costs generally reached a high between 2.0 to 3.0 GNP growth regardless of the aircraft mix examined. An underlying cause was the situation where sufficient demand for passenger aircraft was present at the 2.0 percent level, yet insufficient air cargo traffic combined with lower hold cargo capability depressed the need for transitioning convertible aircraft. Appendix O provides a summary of net discounted program costs for incremental increases in deflated GNP and the percentage of PRM flown by B-747B and B-727 aircraft as outlined in Figure 23.

SITUATION C

The final situation was considered as representative of real world constraints. To investigate the impact of varying levels of GNP

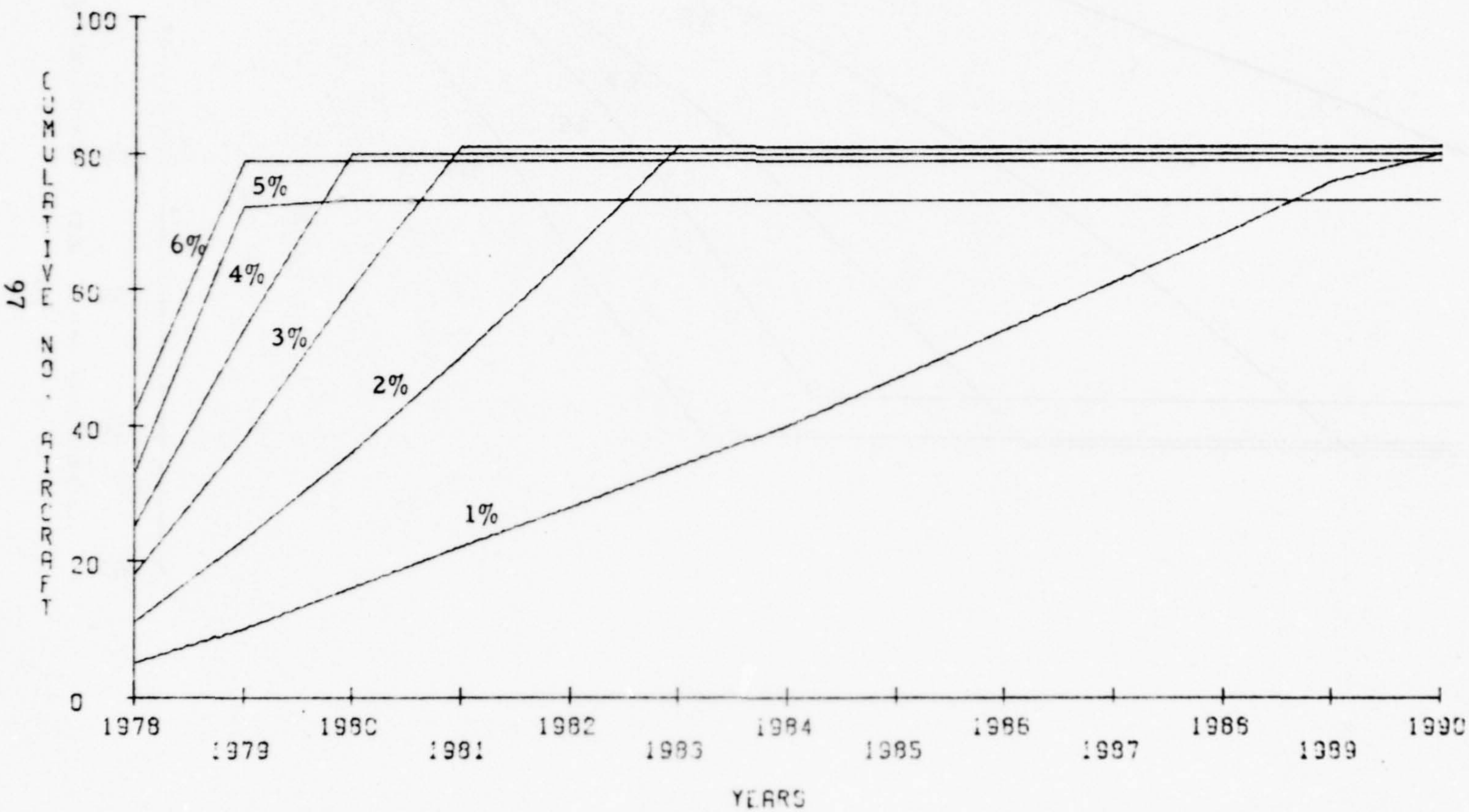

Fig. 21. Situation B: Time-phased Flow of Convertibles with 30 Percent Annual PRM Flown by B-747B Aircraft

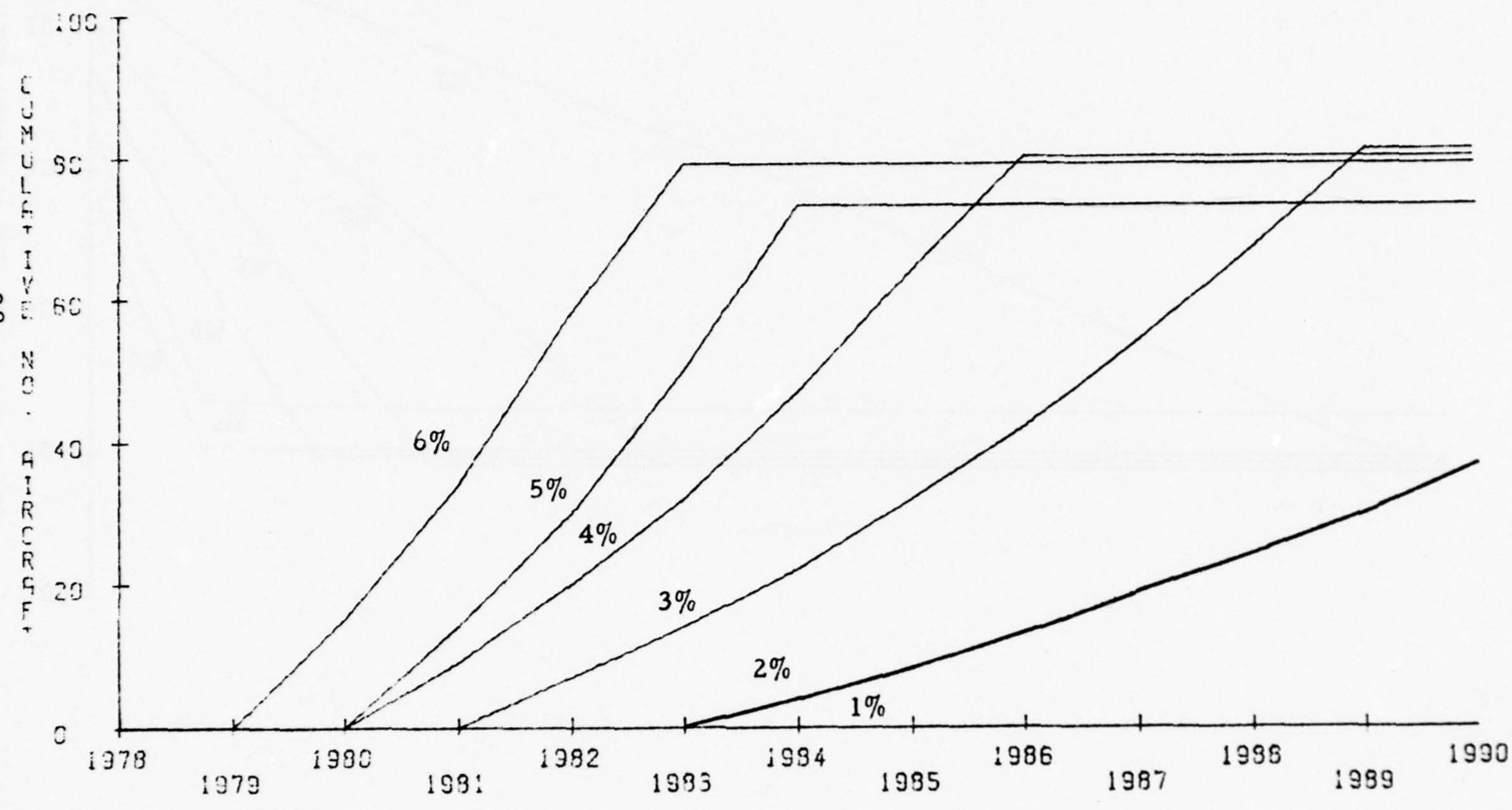

Fig. 22. Situation B: Time-phased Flow of Convertibles to Freighter Modes with 30 Percent Annual PRM Flown by B-747B Aircraft

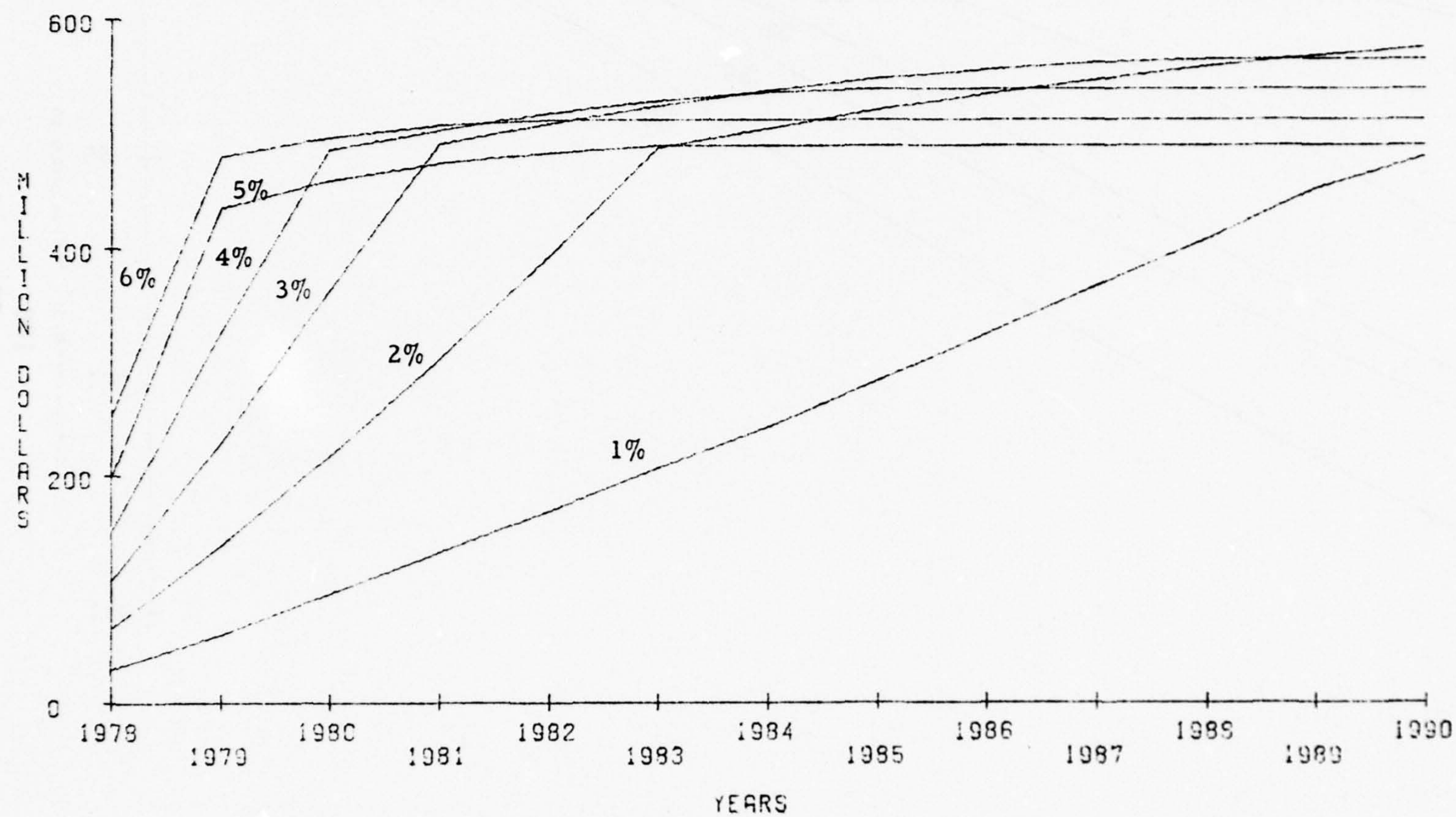

Fig. 23. Situation B: Time-phased Flow of Program Costs with 30 Percent Annual PRM Flown by B-747B Aircraft

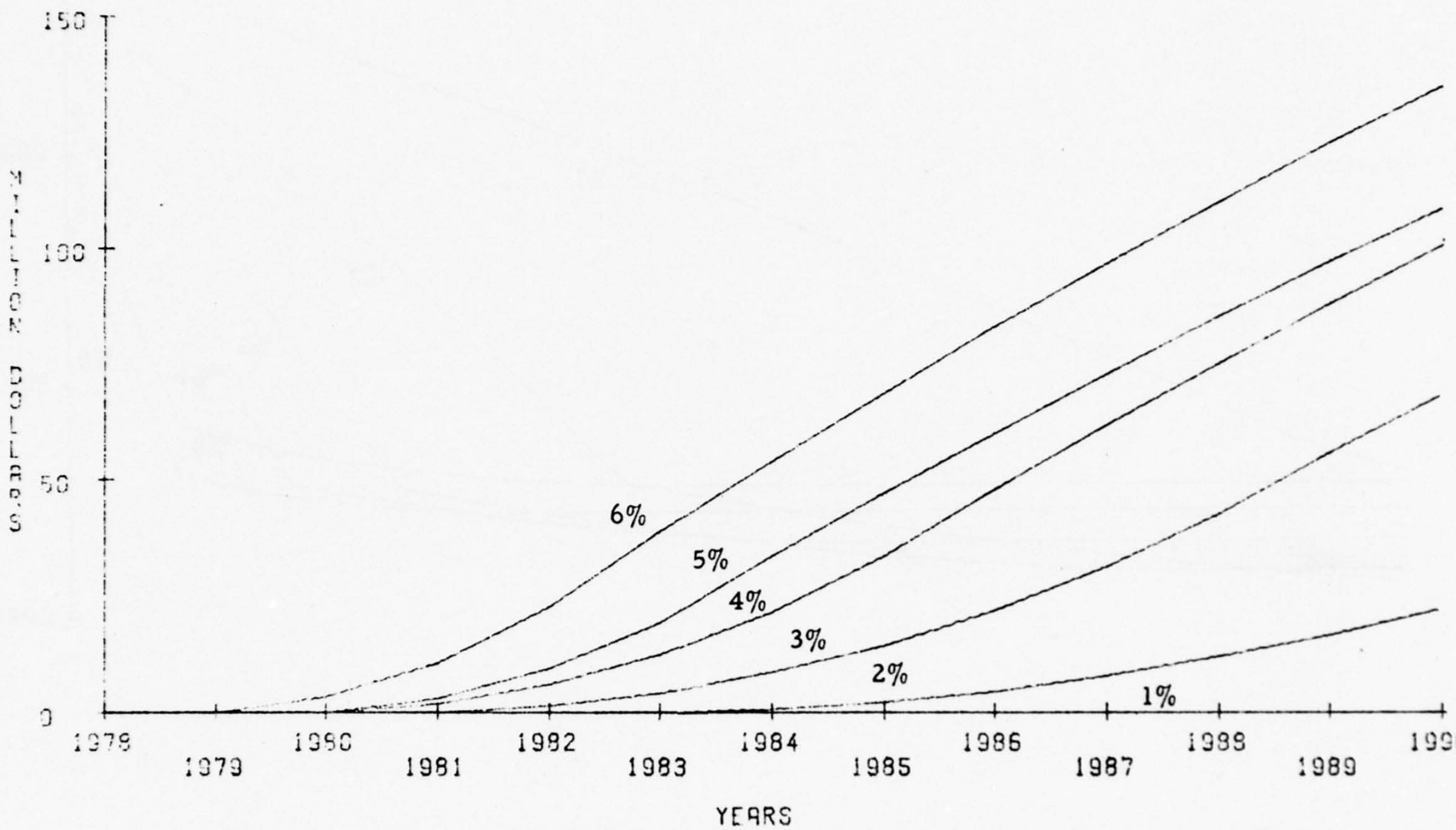

Fig. 24. Situation B: Time-phased Flow of Air Carrier Reimbursements with 30 Percent Annual PRM Flown by B-747B Aircraft

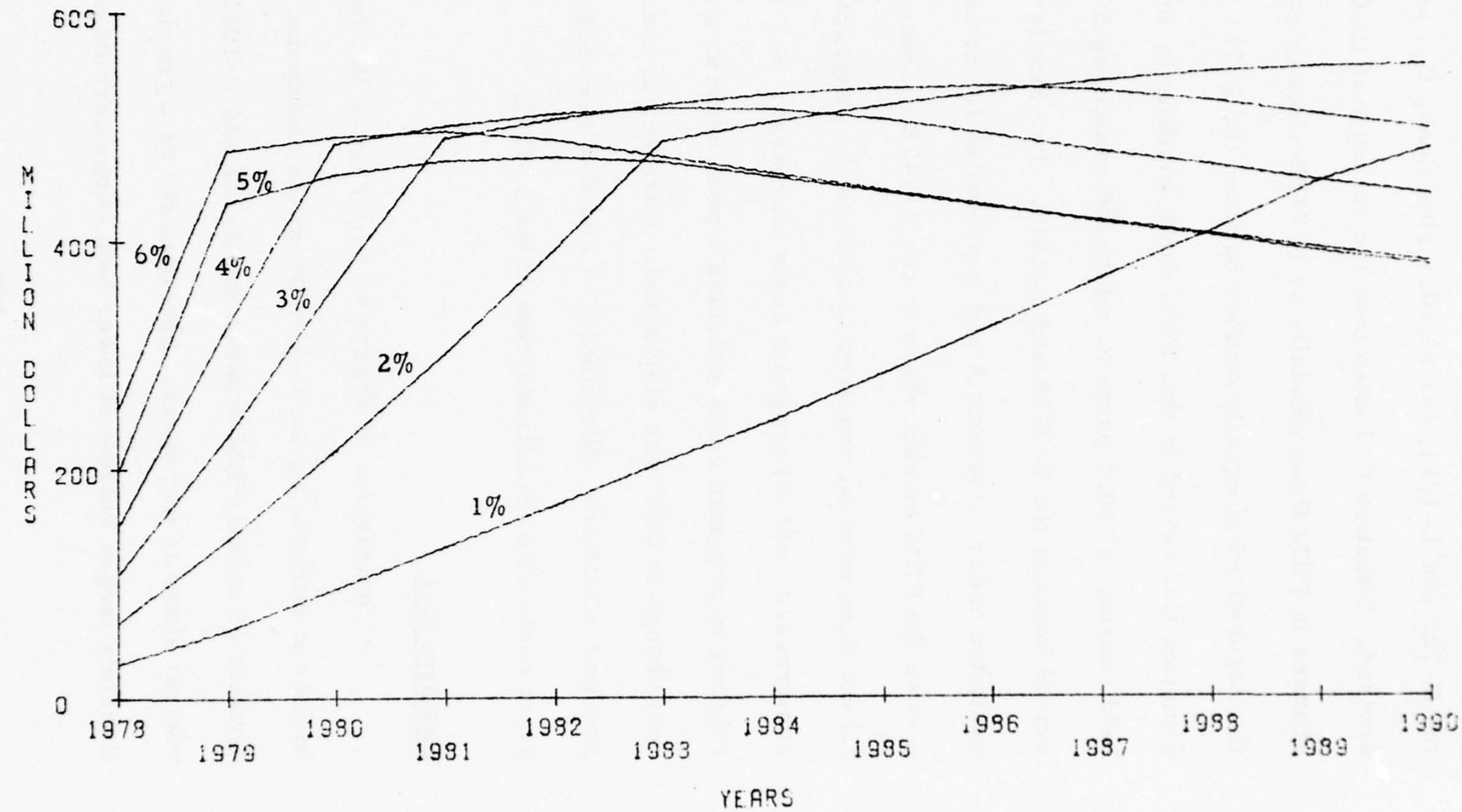

Fig. 25. Situation B: Time-phased Flow of Net Discounted Program Costs with 30 Percent Annual PRM Flown by B-747B Aircraft

growth and the effect of changes in the percentage of PRM flown by the B-727 and L-1011, two similar situations, C-1 and C-2, were devised. Situation C-1 examined the outcome of 10.0 percent changes in PRM flown annually by B-747B aircraft contrasted with the residual PRM equally divided between the B-727 and L-1011. Situation C-2 varied in that PRM flown annually by the B-727 was held constant at 50.0 percent, while the remaining 50.0 percent was varied between the B-747B and L-1011. Two similar relationships exhibited under ituations A and B prevailed for Situations C-1 and C-2 as the PRM market share of the B-747B increased; namely, (1) the time interval required to achieve the program goal was compressed, and (2) program costs increased. A third relationship relating to program costs reaching a peak between a 2.0 to 3.0 percent change in GNP was also noted. Further, in contrast to the previous situations, Situations C-1 and C-2 resulted in higher program costs with the introduction of the L-1011.

Situation C-1

A comparison of Figure 19 with Figure 26 illustrates the impact of introducing the L-1011 from the standpoint of an equal division of annual PRM between the B-727 and L-1011 as the B-747B market share is increased. Specifically, as a result of the proportionately larger volume of lower hold cargo carried by the L-1011,

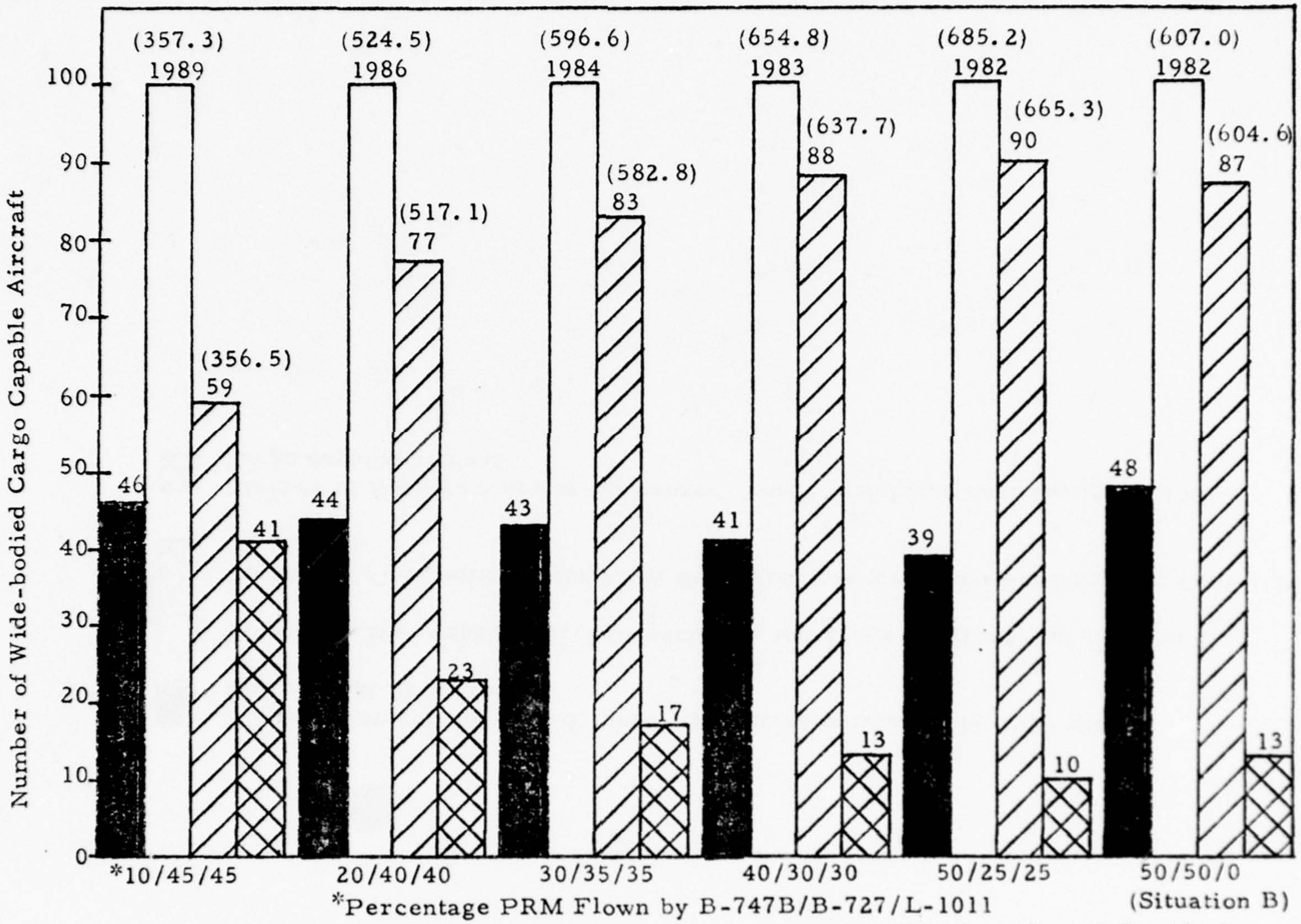

Fig. 26. Situation C-1 for a 2.0 Percent Average Annual GNP Growth with Residual PRM Equally Divided between B-727 and L-1011 Aircraft

Non-government-sponsored "pure" freighters purchased by 1990 without Government Program.

Year 100 cargo capable aircraft available and gross program cost (million $).

Number of Government-sponsored Convertible Aircraft and Net Program Cost (million $).

Number of Non-government-sponsored "pure" freighters contributing to 100 cargo capable aircraft.

program costs are increased due to less non-government-sponsored freighters contributing to the program goal. Further, as the percentage of PRM allocated to the L-1011 diminishes, the gap between the number of non-government sponsored freighters diminishes from 29.3 percent for a 10-90-0 versus 10-45-45 market split to 18.8 percent for a 50-50-0 versus 50-25-25 market split.

Figure 26 compared with Figure 27 for a 3.0 GNP growth indicates lower net program costs resulted from significantly higher air carrier reimbursement even though: (1) initial investment costs were discounted with a higher discount factor due to earlier entry of the convertibles into the air carrier system, and (2) the number of convertibles entering the system remained virtually constant. In contrast to Situation B at a 3.0 GNP growth level (see Figure 20), annual operating costs did not cease over the program life. However, Figure 27 reveals a slightly higher GNP growth would result in all convertibles transitioning to the freighter mode. Figures 28 and 29 illustrate the time-phased flow of convertibles entering the system and exiting to a freighter mode for a 30-35-35 market split, at various levels of economic activity, respectively. The main computer program and associated output for the 30-35-35 market split is contained in Appendix T. With the exception of a 10-45-45 market split, the program goal was achieved by 1990 under Situation C-1 at the 1.5 percent GNP level. Additionally, at the 1.0 percent level, 10-45-45, 20-40-40,

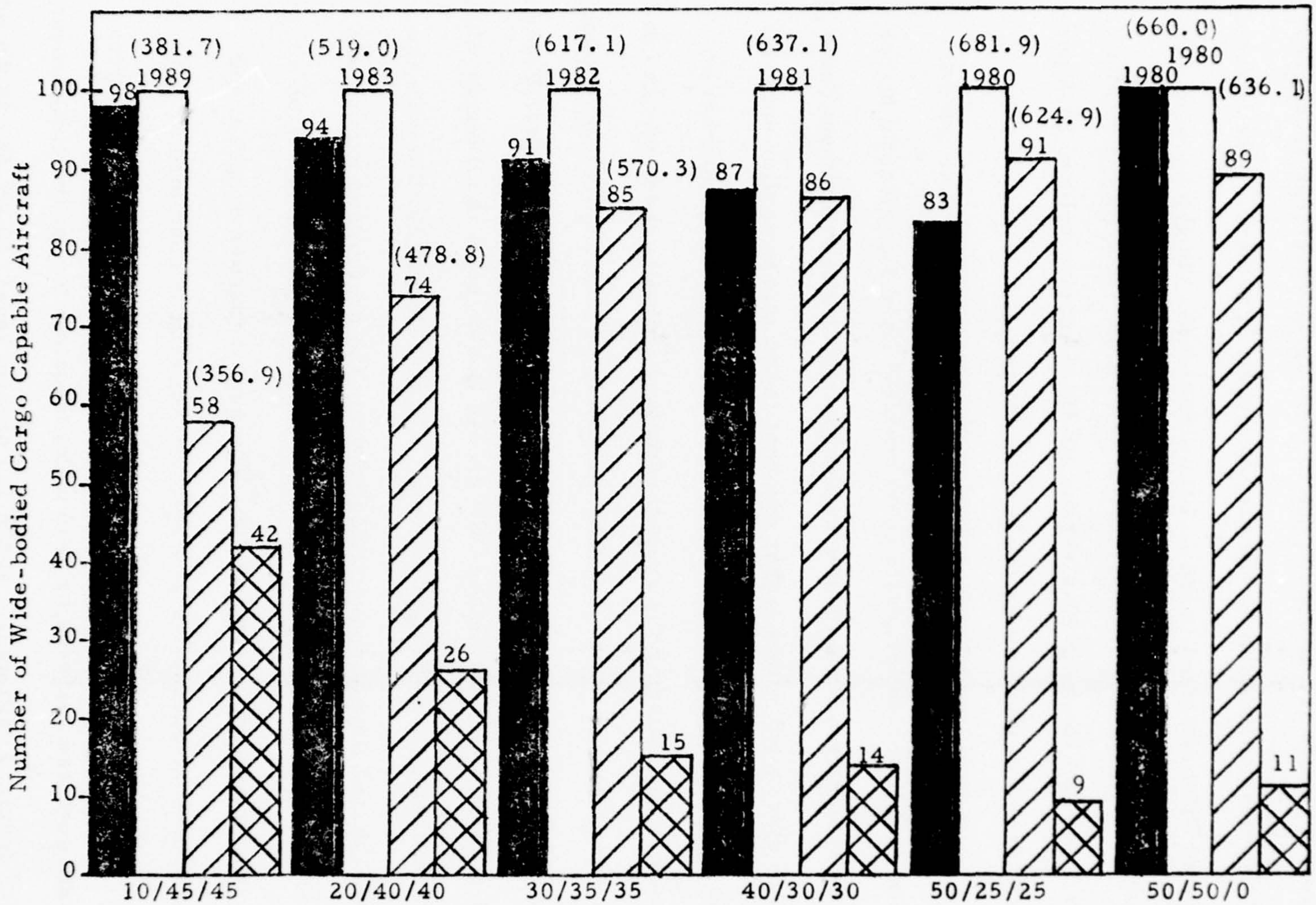

Fig. 27. Situation C-1 for 3.0 Percent Average Annual GNP Growth

- ■ Non-government-sponsored "pure" freighters purchased by 1990 without Government Program.
- □ Year 100 cargo capable aircraft available and gross program cost (million $).
- ▨ Number of Government-sponsored Convertible Aircraft and Net Program Cost (million $).
- ⊠ Number of Non-government-sponsored "pure" freighters contributing to 100 cargo capable aircraft.

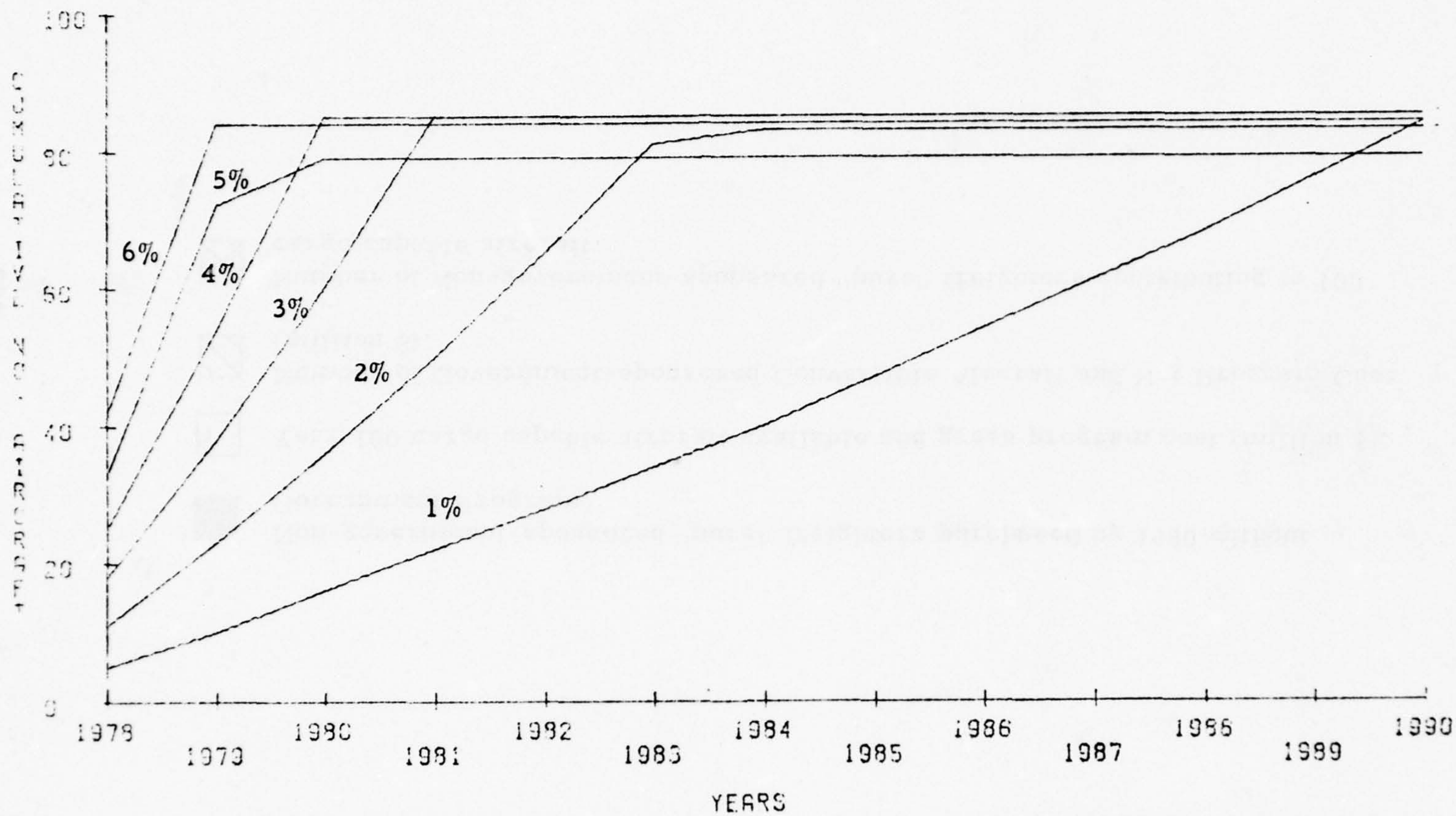

Fig. 28. Situation C-1: Time-phased Flow of Convertibles with 30 Percent Annual PRM Flown by B-747B Aircraft

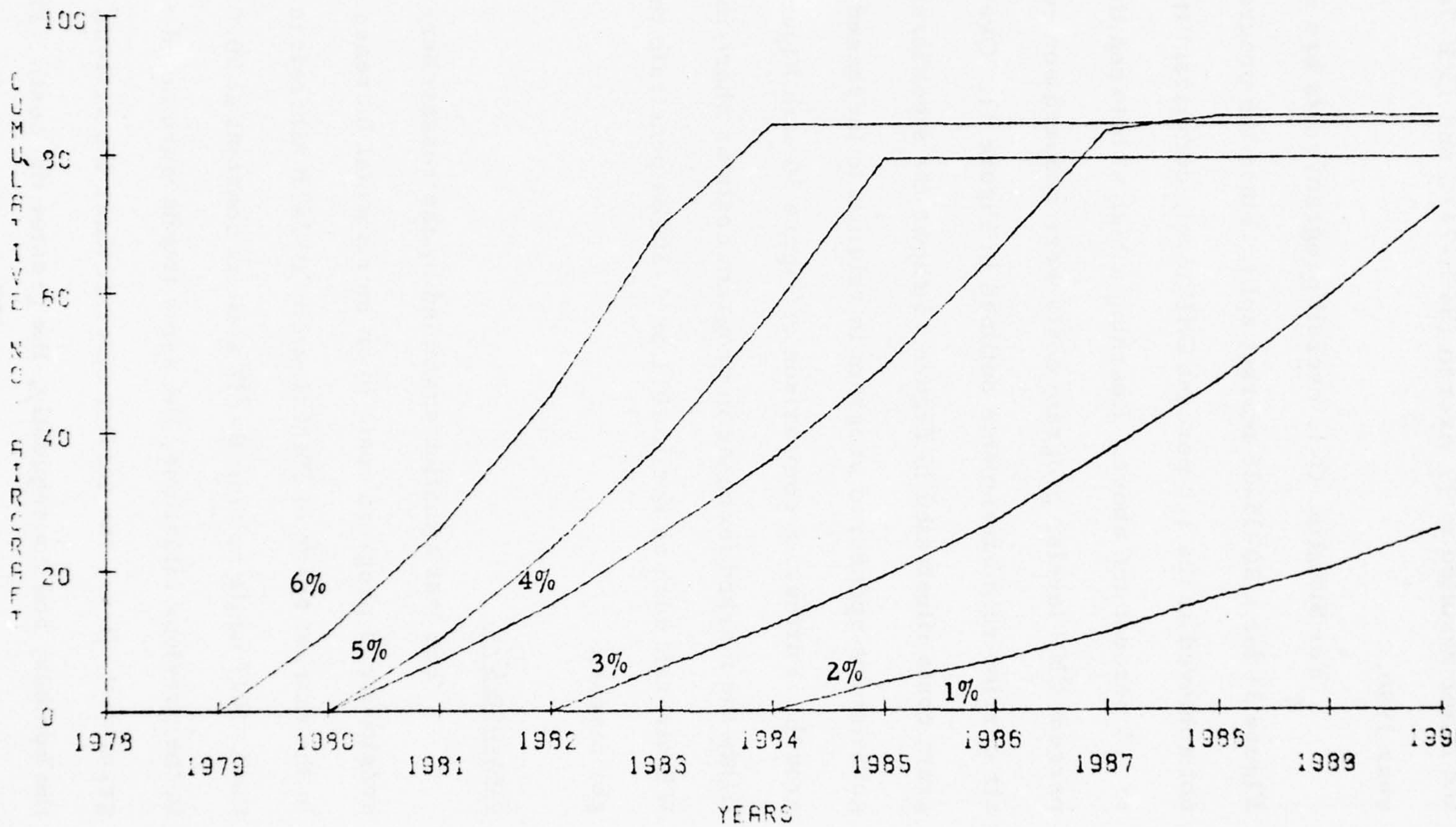

Fig. 29. Situation C-1: Time-phased Flow of Convertibles to Freighter Mode with 30 Percent Annual PRM Flown by B-747B Aircraft

and 30-35-35 market splits failed to yield the program goal; however, the latter resulted in 99 aircraft (84 B-747C and 15 B-747F) by the year 1990.

For Situation C-1, overall program costs are shown in Figure 31 for a 30-35-35 market split. Since the program goal was not achieved at the 1.0 percent GNP level, comparability is limited to 1.5 percent and above. Reaching a high at between the 2.0 to 3.0 percent GNP levels, program costs were reduced somewhat through air carrier reimbursements outlined in Figure 31. Overall net program costs illustrated in Figure 32 shows the significant impact on a government-sponsored program in relation to increased economic growth. Further, a comparison of Figure 30 with Figure 32 highlights the marked increase in program costs as short/medium range WB aircraft such as the L-1011 or A-300B4 penetrate the air passenger market.

Situation C-2

The last situation examined by the researchers was the sensitivity of program costs to an incremental increase (or decrease) in the market share of PRM flown by B-747B aircraft in relation to the L-1011 while holding B-727 activity constant at 50.0 percent. As in the previous situations, the same trends were noted relating program costs (i.e., the earlier aircraft enter the system, the greater the number, and consequently, the greater the cost). The relative

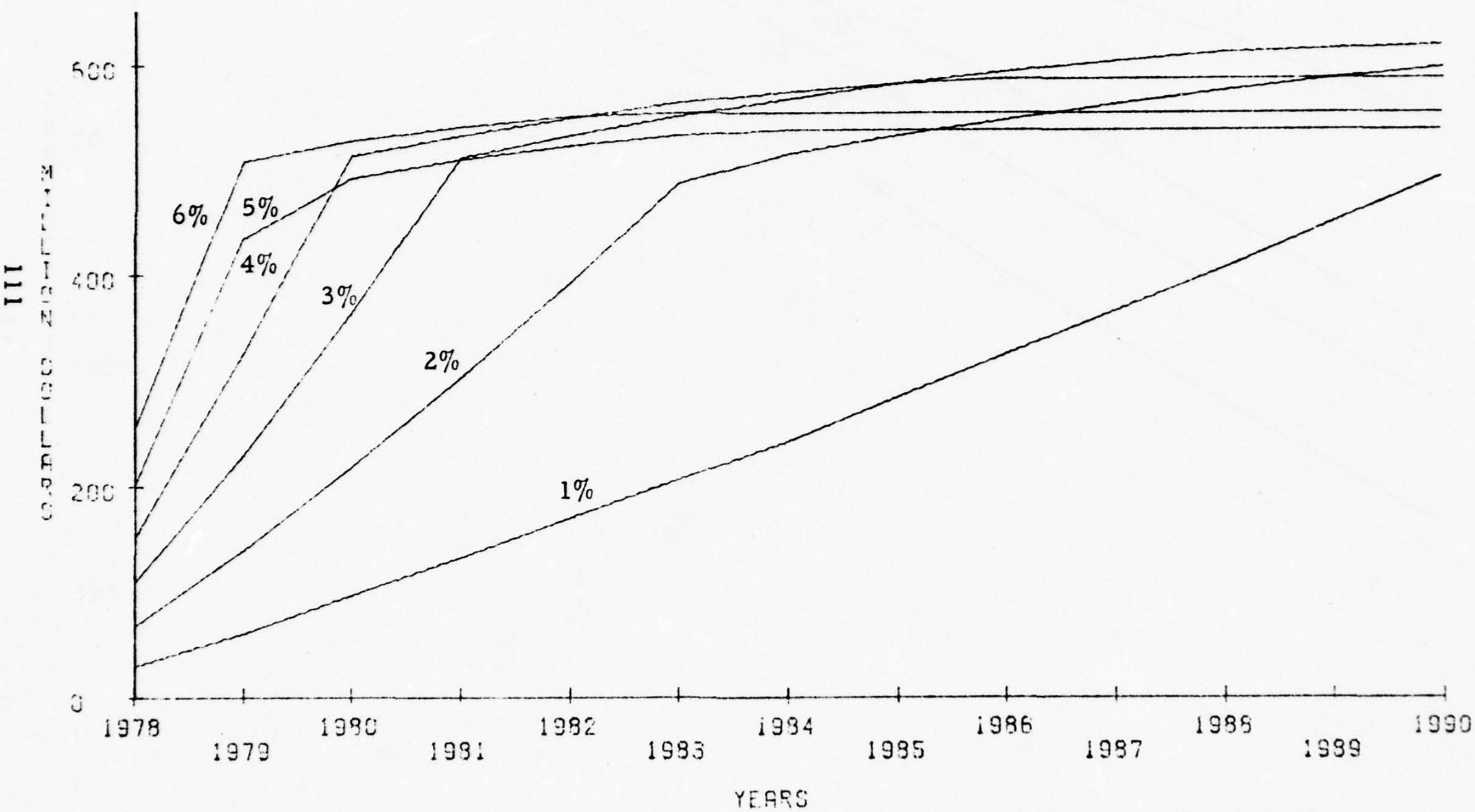

Fig. 30. Situation C-1: Time-phased Flow of Discounted Program Costs with 30 Percent Annual PRM Flown by B-747B Aircraft

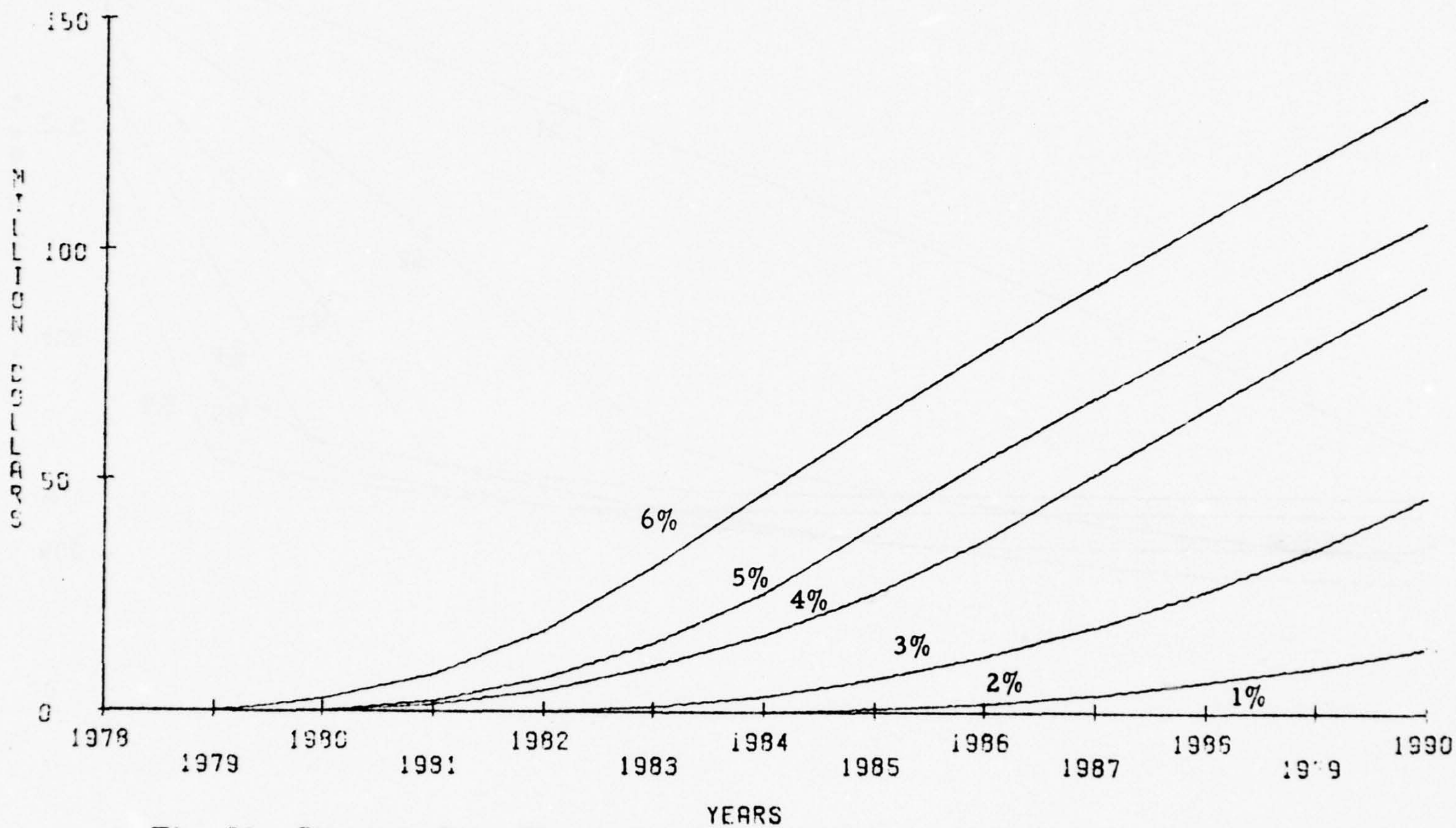

Fig. 31. Situation C-1: Time-phased Flow of Discounted Air Carrier Reimbursements with 30 Percent of Annual PRM Flown by B-747B Aircraft

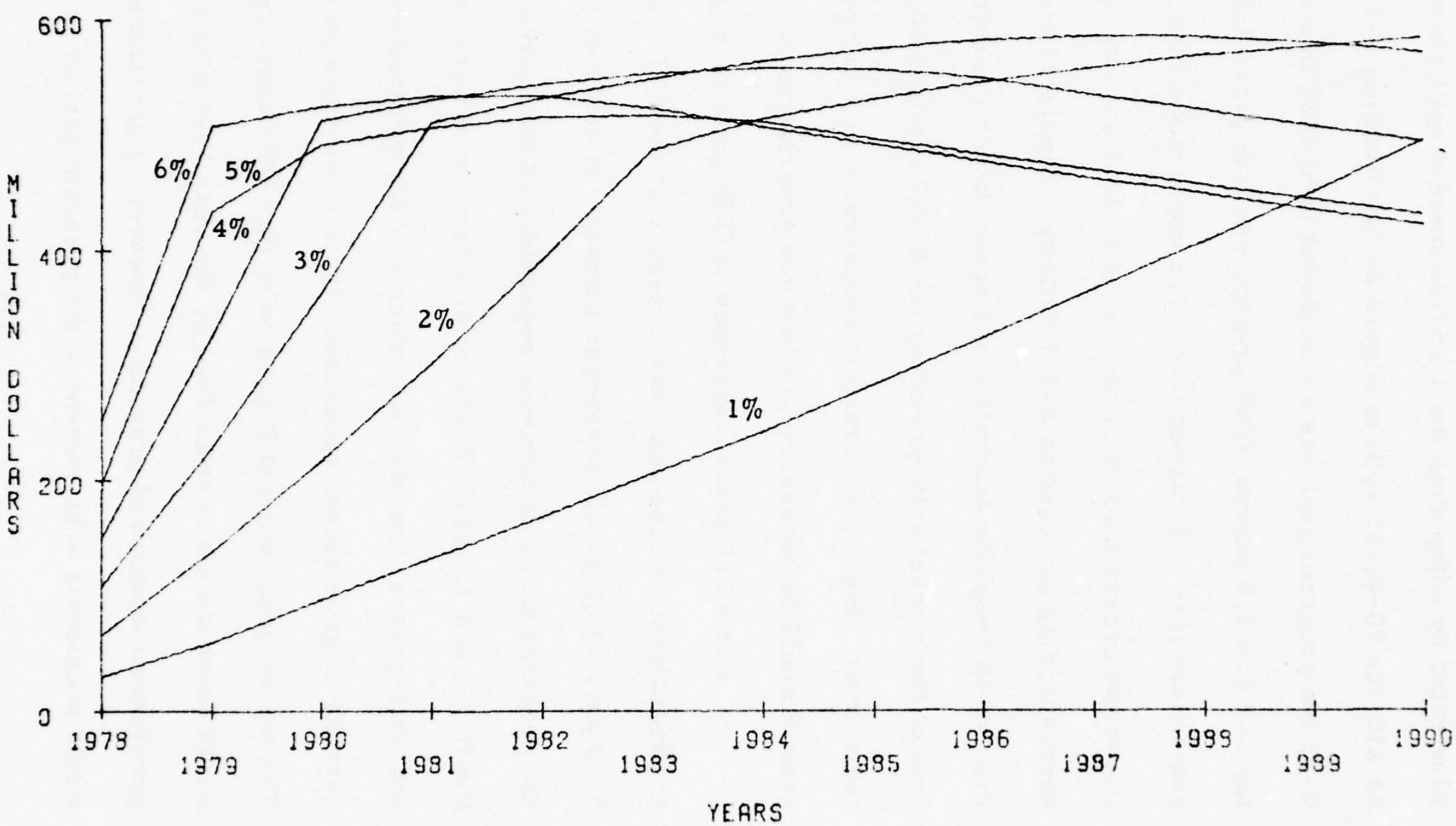

Fig. 32. Situation C-1: Time-phased Flow of Net Discounted Program Costs with 30 Percent of Annual PRM Flown by B-747B Aircraft

importance of the L-1011's market share on program costs are best illustrated by comparing the 20-50-30 market split shown in Figure 33 with the 20-40-40 split in Figure 26 for Situation C-1. In Situation C-1, the program goal was not achieved until 1986 in contrast to 1985 for C-2 at a 2.0 percent GNP growth, yet both gross and net program costs were less in Situation C-2. The observation highlights the impact on program costs of decreased L-1011 activity offset by a corresponding increase in B-727 activity. Figure 33 indicates a maximum of 48 freighter aircraft would enter the air carrier fleet regardless of the market split providing the B-727 retained 50.0 percent of the market. Hence, government sponsorship at a 2.0 percent GNP growth would be necessary to attain the program goal.

For a 3.0 percent increase in GNP growth, Figure 34 shows the significance of the continued presence of the B-727 with a constant 50.0 percent of the air passenger market. In contrast to Figure 33, the program goal was achieved regardless of the market split between the B-747 and L-1011. Further, program costs were reduced while the time-phased flow of convertibles was compressed even though the quantity of government-sponsored aircraft remained relatively stable. The major implication of Figure 34 is that 100 cargo capable aircraft would enter the air carrier fleet by the year 1990 with or without a government-sponsored program. However, a government program would accelerate achievement of the program goal by as much as nine

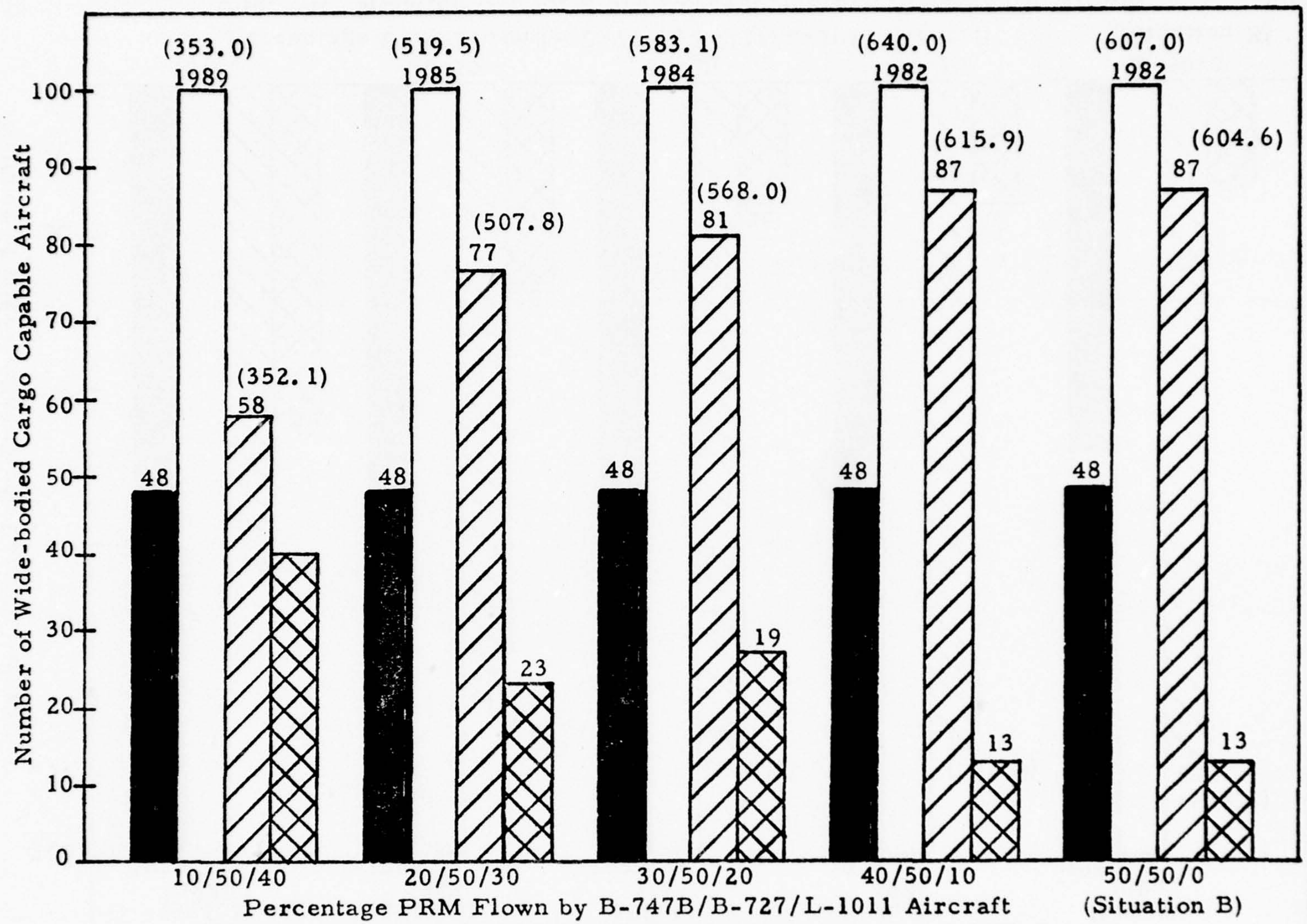

Fig. 33. Situation C-2 for a 2.0 Percent Average Annual GNP Growth

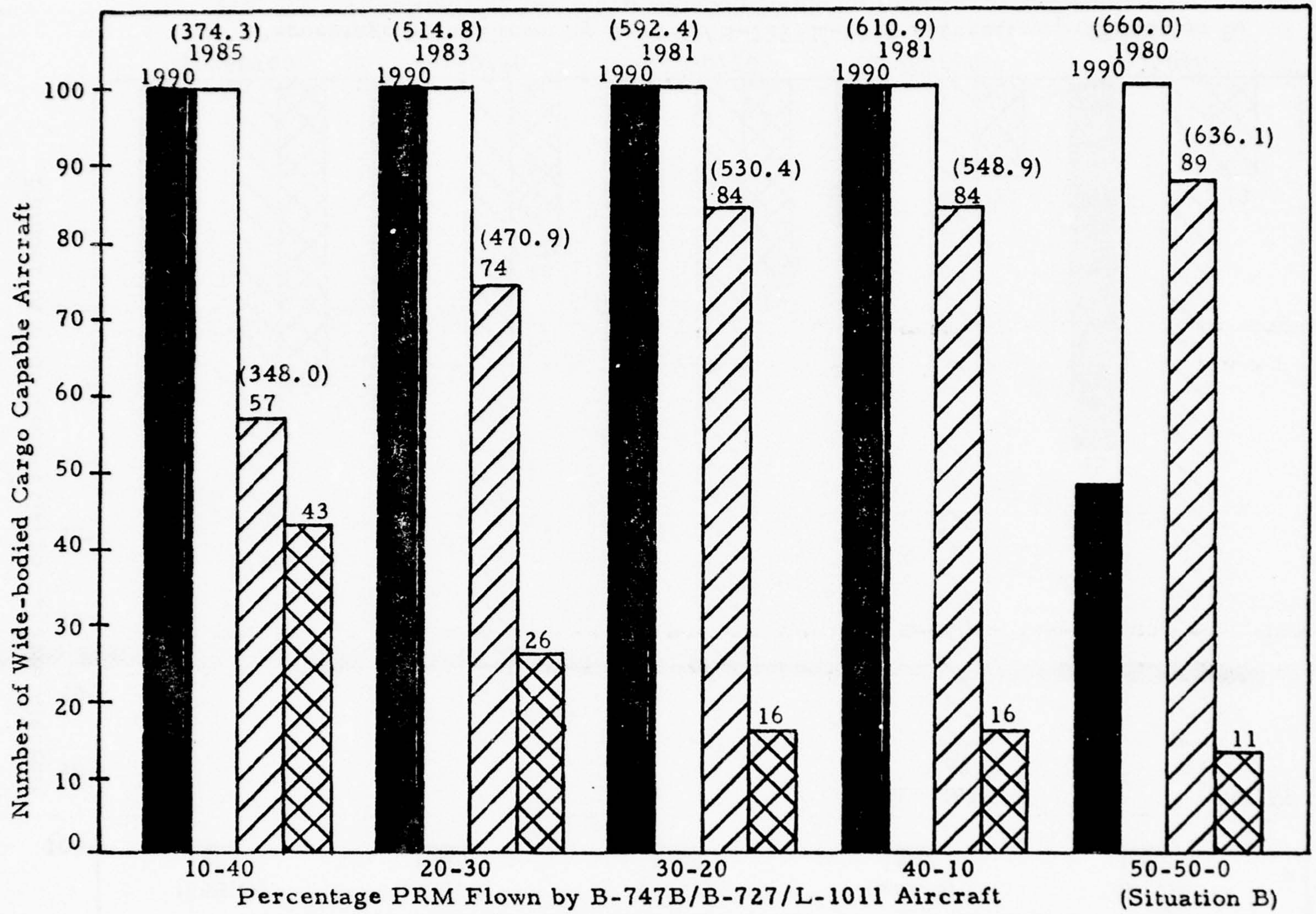

Fig. 34. Situation C-2 for a 3.0 Percent Average Annual GNP Growth

- Non-government-sponsored "pure" freighters purchased by 1990 without Government Program.
- Year 100 cargo capable aircraft available and gross program cost (million $).
- Number of Government-sponsored Convertible Aircraft and Net Program Cost (million $).
- Number of Non-government-sponsored "pure" freighters contributing to 100 cargo capable aircraft.

years depending on market penetration of short/medium range WB aircraft.

The time-phased flow of convertible aircraft entering the system and transitioning to the freighter mode is depicted in Figures 35 and 36 for a market mix of 30-50-20. With the exception of a modest 0.5 percent increase in GNP, results indicated the program goal could be achieved ranging from one year with a large sustained average annual growth of over 6.0 percent to as late as 1990 in the case of a 1.0 percent growth. Figures 37, 38, and 39 graphically portray cumulative discounted program costs, air carrier reimbursements, and net program costs, respectively. As in the case of all situations examined previously, maximum program costs occur between the 2.0 to 3.0 percent GNP growth level.

COMPARISON OF SITUATIONS

The earlier portion of this chapter provided an insight to the complexity of examining all aircraft mixes simultaneously with varying levels of deflated GNP growth for each program year. Bar charts were used to depict the outcome for each situation while detailed illustrations were used to depict a specific aircraft mix ranging throughout the program life. This section will now tie together the results of the computer model based on the projected outcome of a government sponsored program beginning in the year 1978 and terminating in 1990.

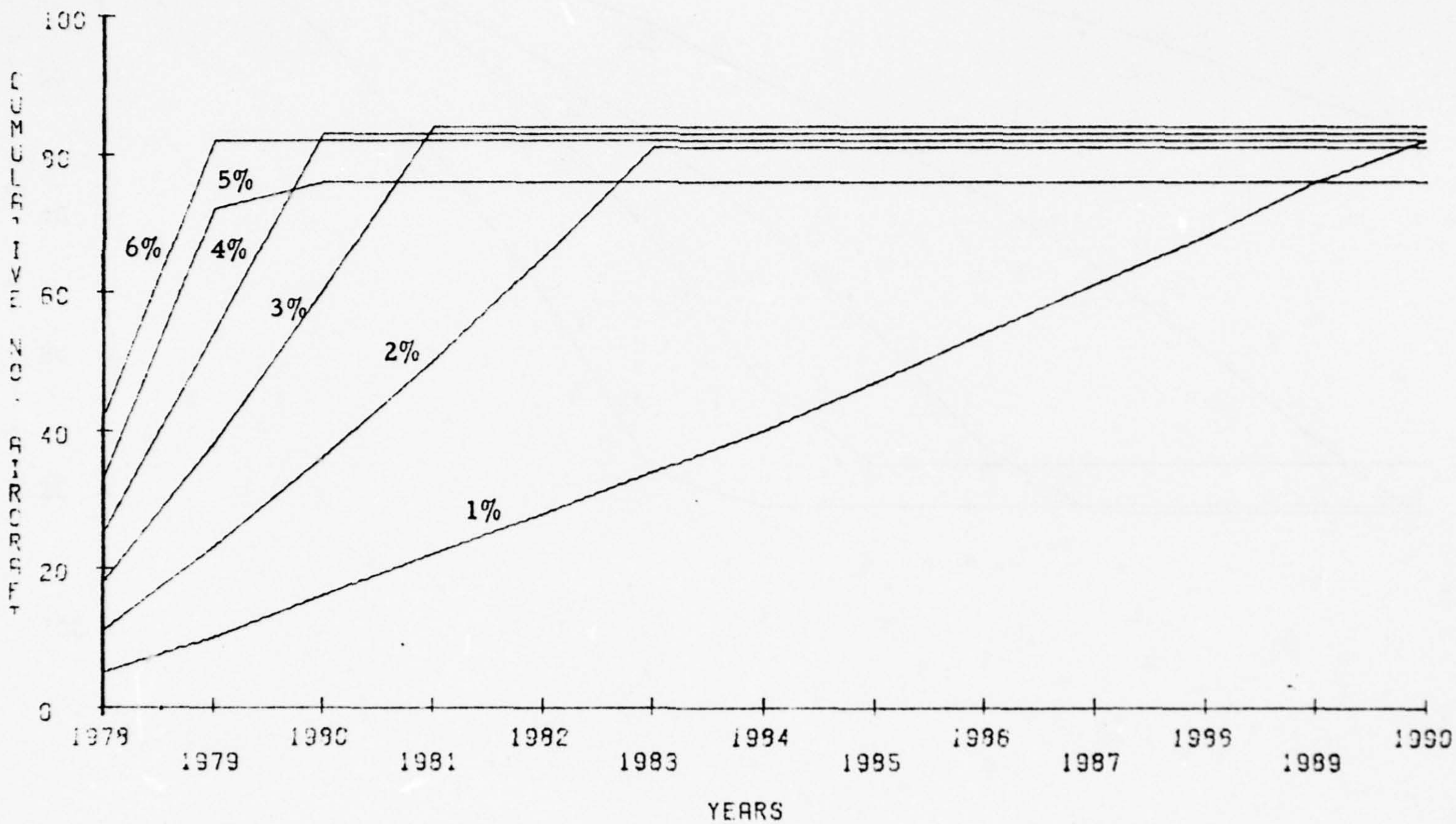

Fig. 35. Situation C-2: Time-phased Flow of Convertibles with 30 Percent Annual PRM Flown by B-747B Aircraft

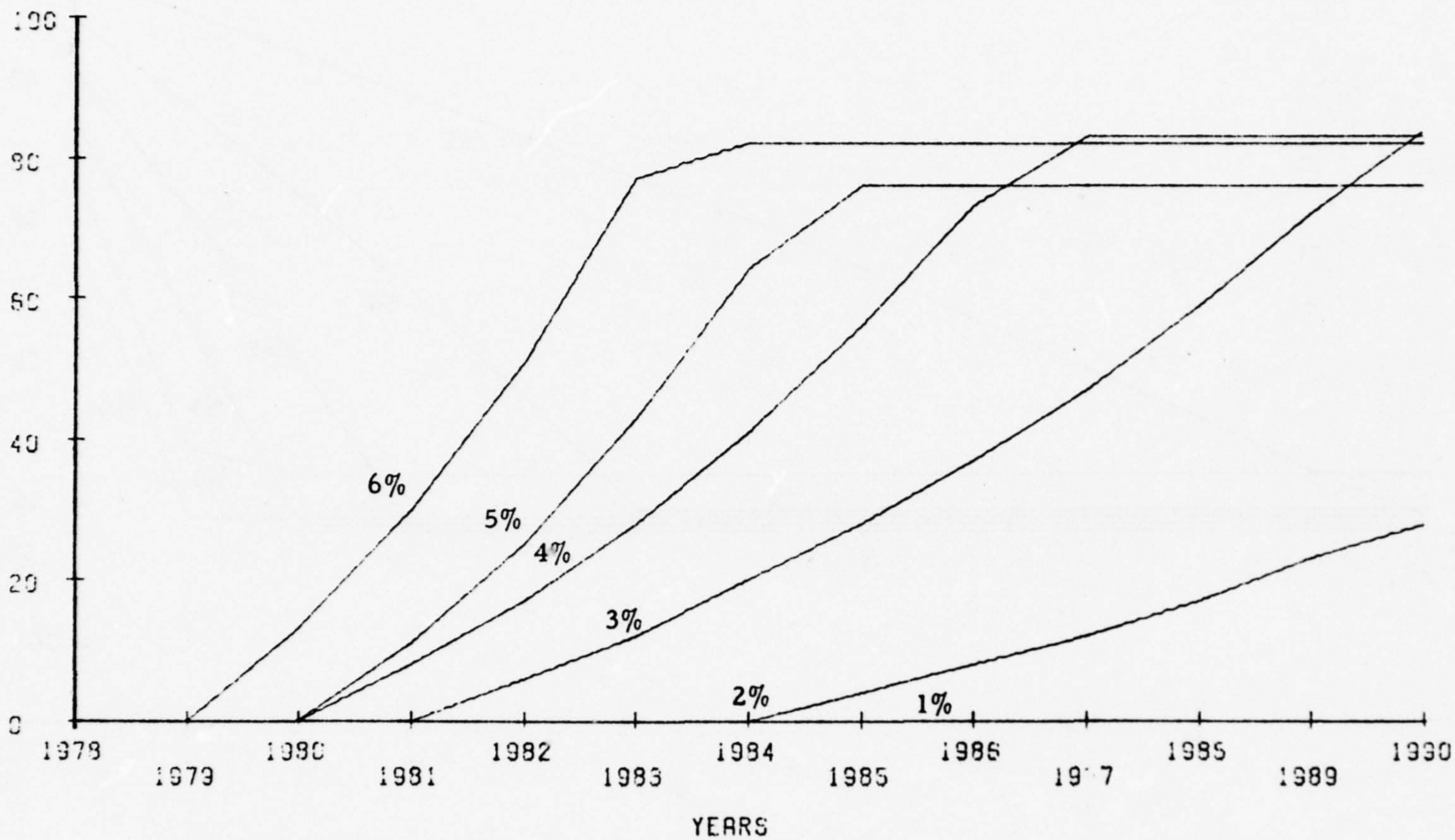

Fig. 36. Situation C-2: Time-phased Flow of Convertibles to Freighter Mode with 30 Percent Annual PRM Flown by B-747B Aircraft

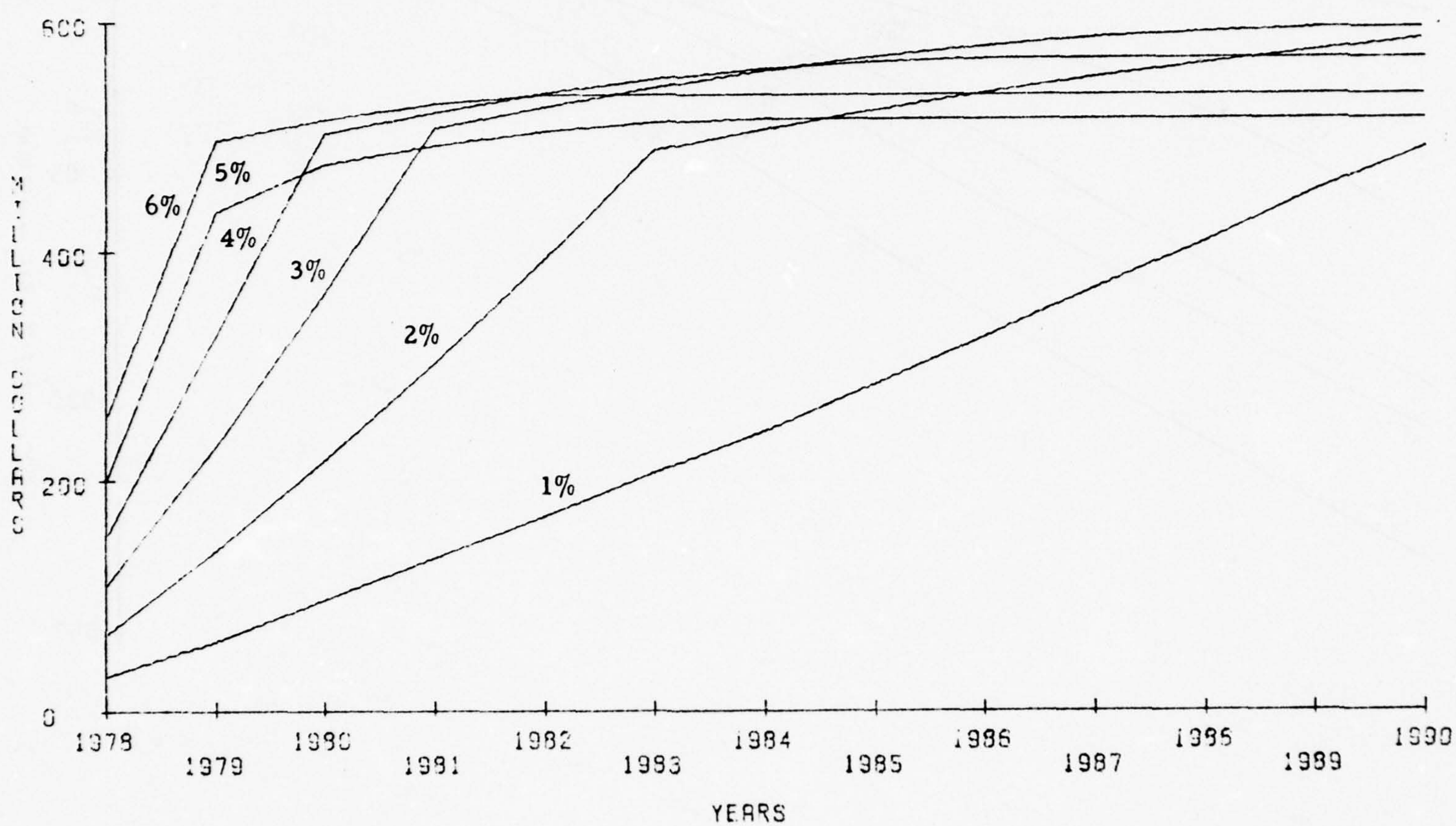

Fig. 37. Situation C-2: Time-phased Flow of Discounted Program Costs with 30 Percent Annual PRM Flown by B-747B Aircraft

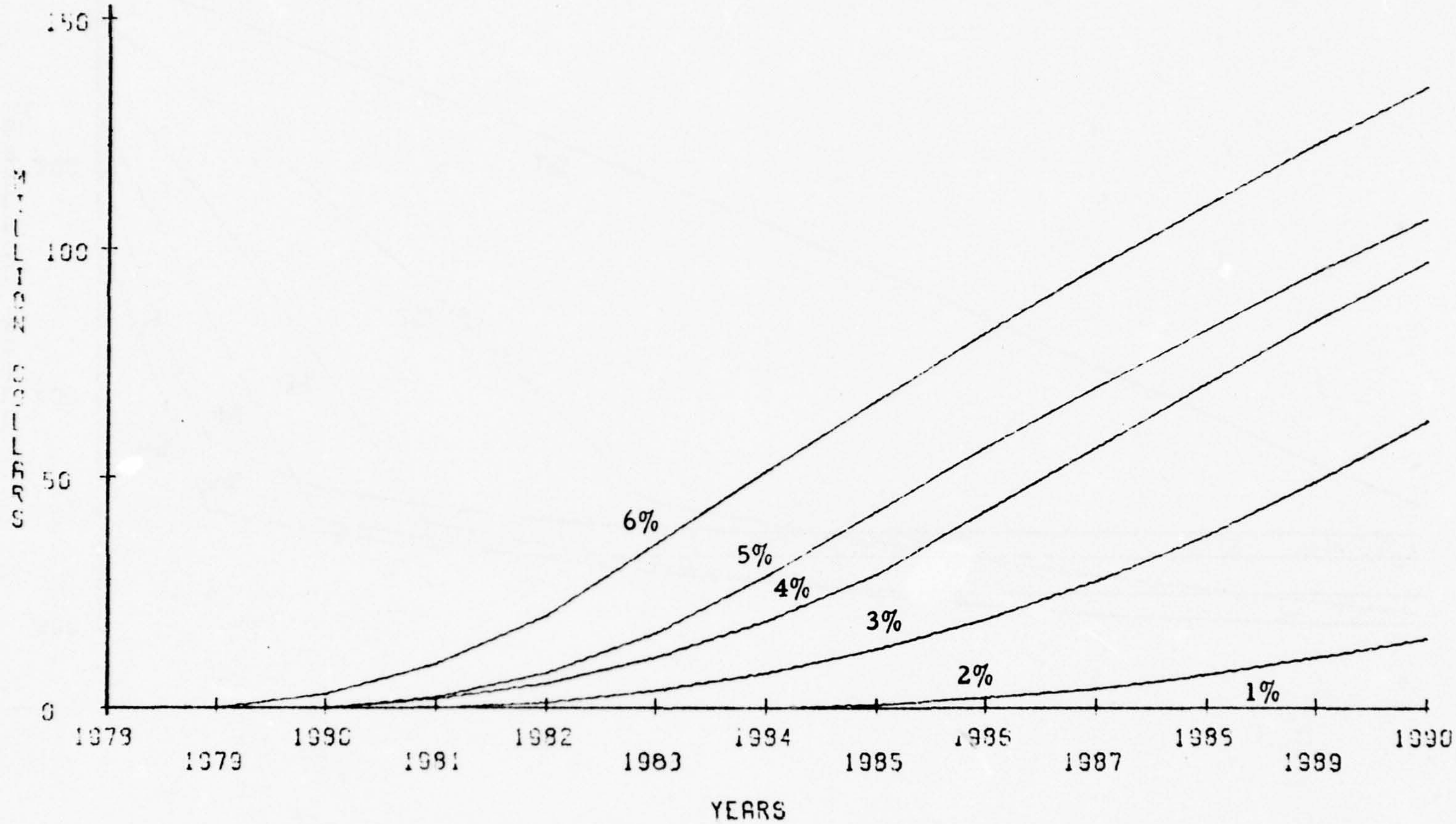

Fig. 38. Time-phased Flow of Discounted Air Carrier Reimbursements with 30 Percent Annual PRM Flown by B-747B Aircraft

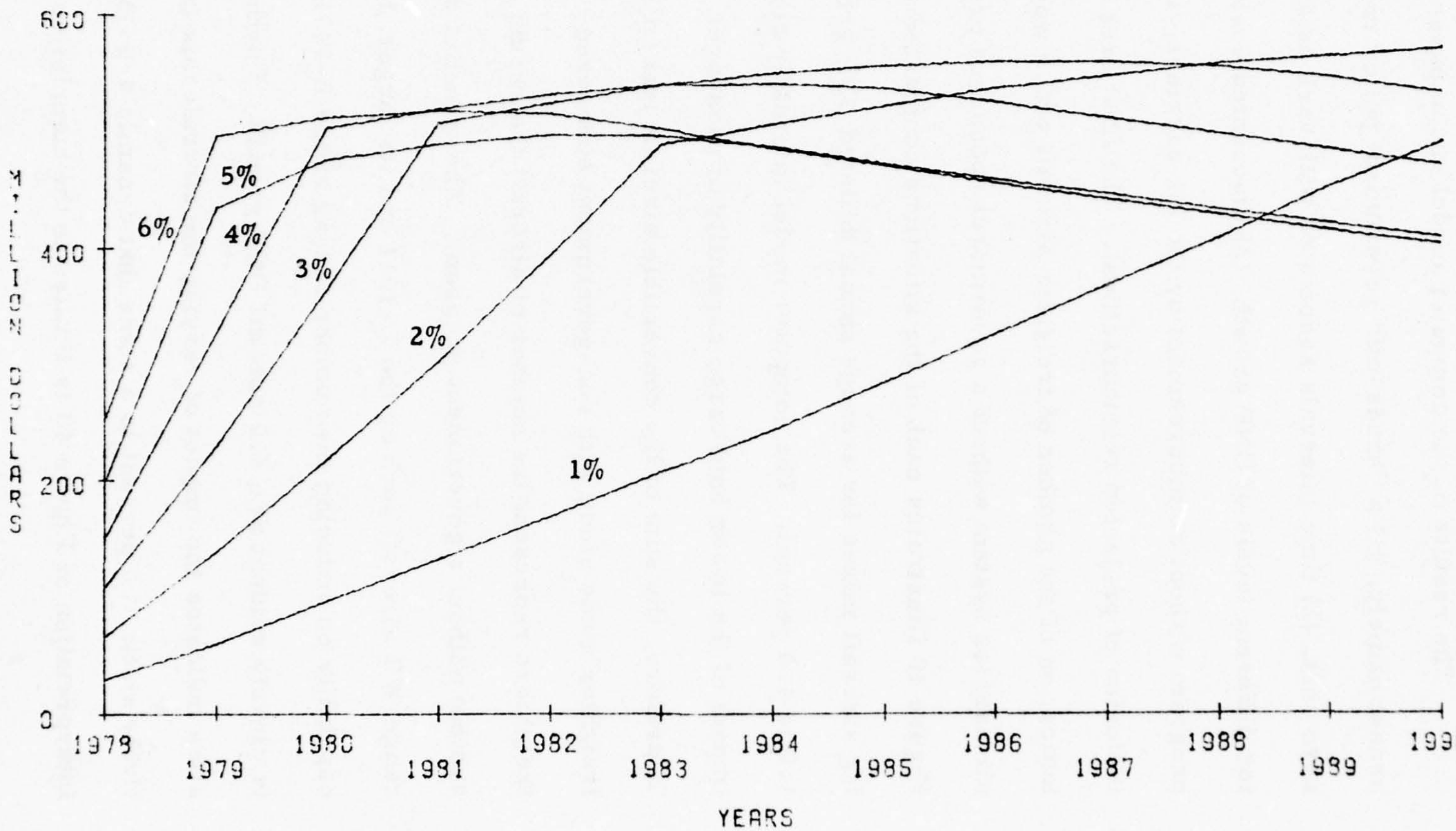

Fig. 39. Time-phased Flow of Discounted Net Program Costs with 30 Percent of Annual PRM Flown by B-747B Aircraft

General

The results of the computer model encompassed four main areas; namely, (1) a "hands-off" government policy resulting in zero cost, (2) time intervals associated with various aircraft mixes for different levels of GNP growth, (3) discounted costs based on a program without reimbursement by the air carriers, and (4) the inclusion of projected reimbursement. The first area provides an indication of the number of freighter aircraft which would enter the air carrier system without a government sponsored program. Figure 40 illustrates each of the situations contrasted with the varying aircraft mixes for average annual deflated GNP growth between 1.0 to 4.0 percent. The computer model internally considered the impact of the lower hold cargo capability of passenger aircraft. Therefore, the sum of the convertible aircraft transitioned to a freighter mode along with non-government sponsored "pure" freighters represent the number of aircraft that would enter the system without a government program. The effect of short/medium range WB aircraft such as the L-1011 and its larger lower hold capability on reducing the number of long range B-747F freighters is clearly evident at a 3.0 percent GNP growth. Further, each situation indicates the impact of varying the aircraft mix from a relatively static 1.0 percent to a somewhat dynamic 4.0 GNP growth. Interpretation of Figure 40 is limited to the cumulative number of

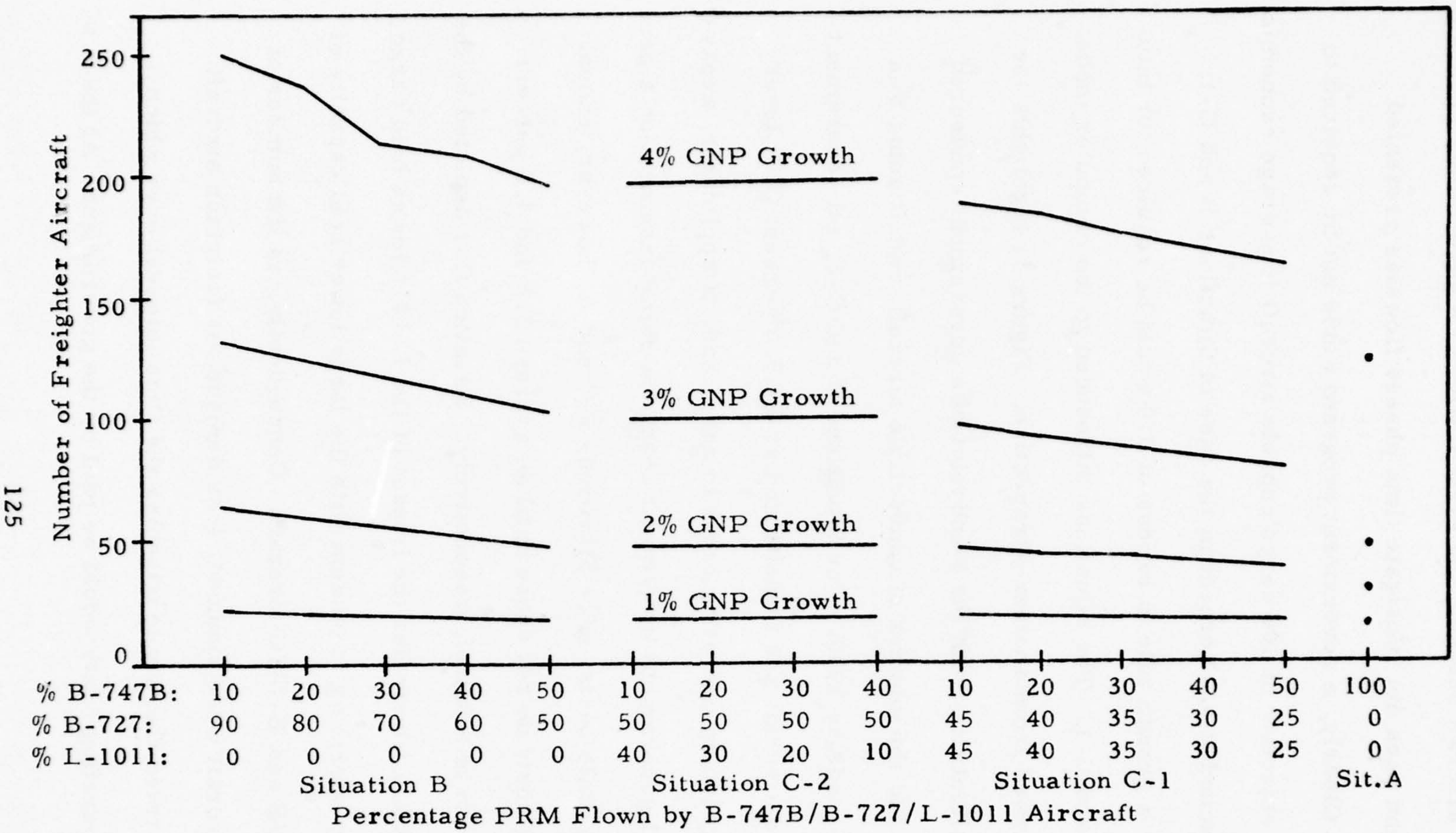

Fig. 40. Total Number of Freighters Achieved by 1990 without Government Sponsorship

freighter aircraft entering the system without a government program by 1990 and does not illustrate time phased flows as presented earlier. Clearly, a government program would not be required to meet the objective of 100 cargo capable aircraft if average economic growth exceeded 3.0 percent in the case of Situations B and C-1; however, a growth rate in excess of 3.0 would be required for Situations A and C-1. The situations introduced to the computer model can be viewed from another perspective. Figure 41 highlights the various situations from the standpoint of a government sponsored program and the number of convertible aircraft transitioning to a freighter mode by 1990. For Situations B and C-2, all government sponsored aircraft are transitioned at the 3.0 percent GNP level thereby reducing operating costs to zero, and, if applicable, repaying initial government investment costs via reimbursement on a per cargo ton-mile basis. For Situations C-1 and A, however, annual operating costs do not cease until an average 3.5 and 4.0 percent GNP growth is attained, respectively. Situation C-1 depicted by the figure vividly illustrates the impact of the L-1011 lower hold cargo capability operating in tandem with the large lower hold capacity of the B-747B and B-747C aircraft. Consequently, as the number of B-727 aircraft were reduced, less demand for freighter aircraft was generated thereby lengthening the time interval over which annual operating costs would be paid by the government. At the 2.0

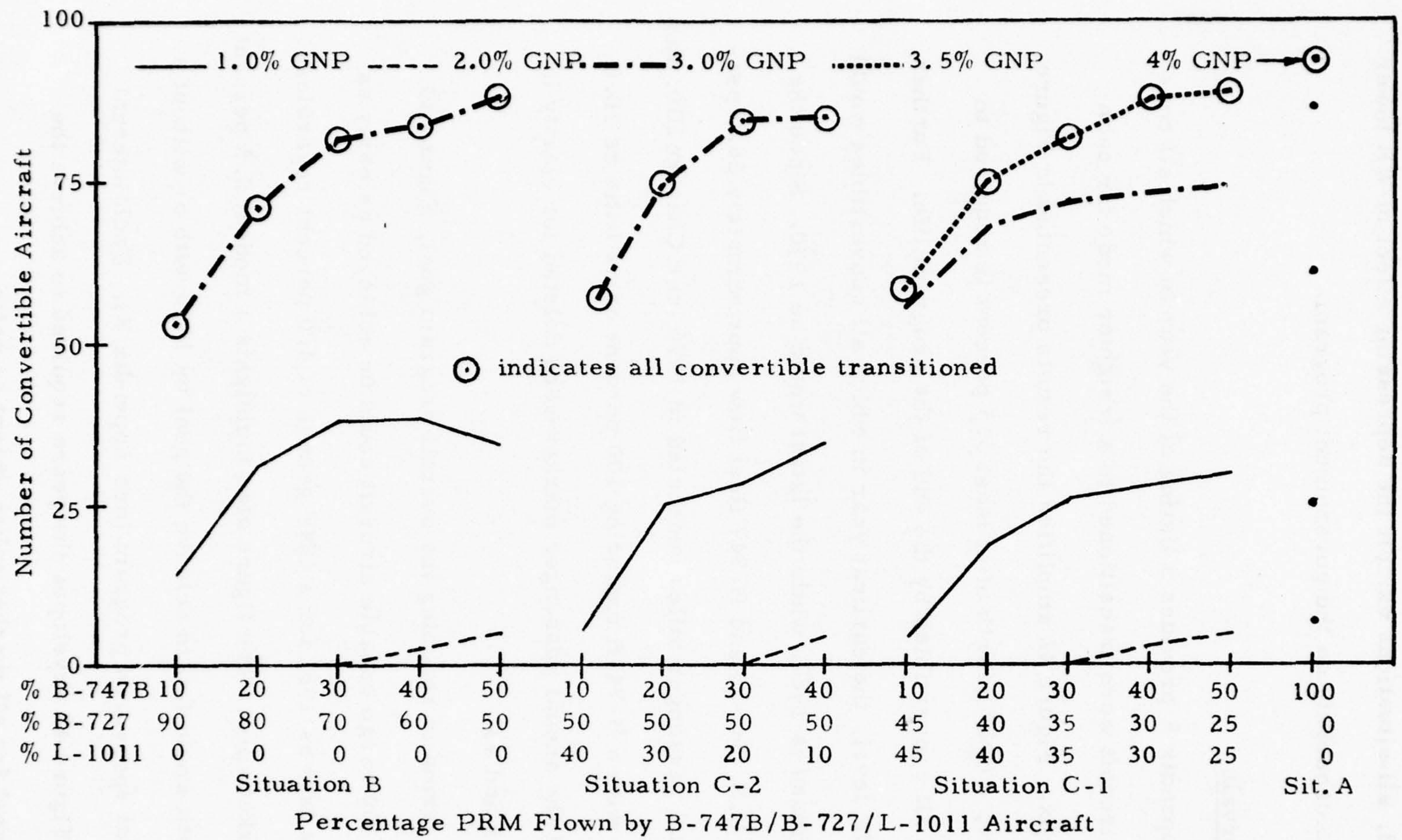

Fig. 41. Total Number of Convertible Aircraft Transitioned to a Freighter Mode by 1990

GNP level, all situations exhibit the depressing effect of WB lower hold cargo capability on the government program.

Time Intervals

Appendix R provides a listing of the year in which all convertible aircraft were transitioned to a freighter mode for each aircraft mix. Figure 42 amplifies the results presented in Figure 41; namely, a GNP growth of at least 3.5 percent is required to transition all convertibles by the end of the program life. Further, at that GNP level, the earliest year in which all convertibles would be transitioned is 1987, while the latest would be 1990. Since the combined U.S. DC-10 and B-747 fleet flew approximately 28.0 percent of total passenger miles generated in 1976 (see Chapter III0, the situations with a B-747B capturing 100 percent or as little as 10.0 percent of the annual passenger market were deleted for clarity in Figures 42 and 43.

In terms of reaching the overall program goal, Figure 43 indicates 100 cargo capable aircraft could be achieved as early as 1979 or as late as 1981 for a GNP growth of 4.0 percent regardless of the market split. The figure also highlights a modest 0.5 percent GNP growth would fail to achieve the goal by 1990 with or without a government sponsored program (see Appendix R). Each interval shown in Figure 43 envelopes the years required to achieve the program goal for all market splits except as noted.

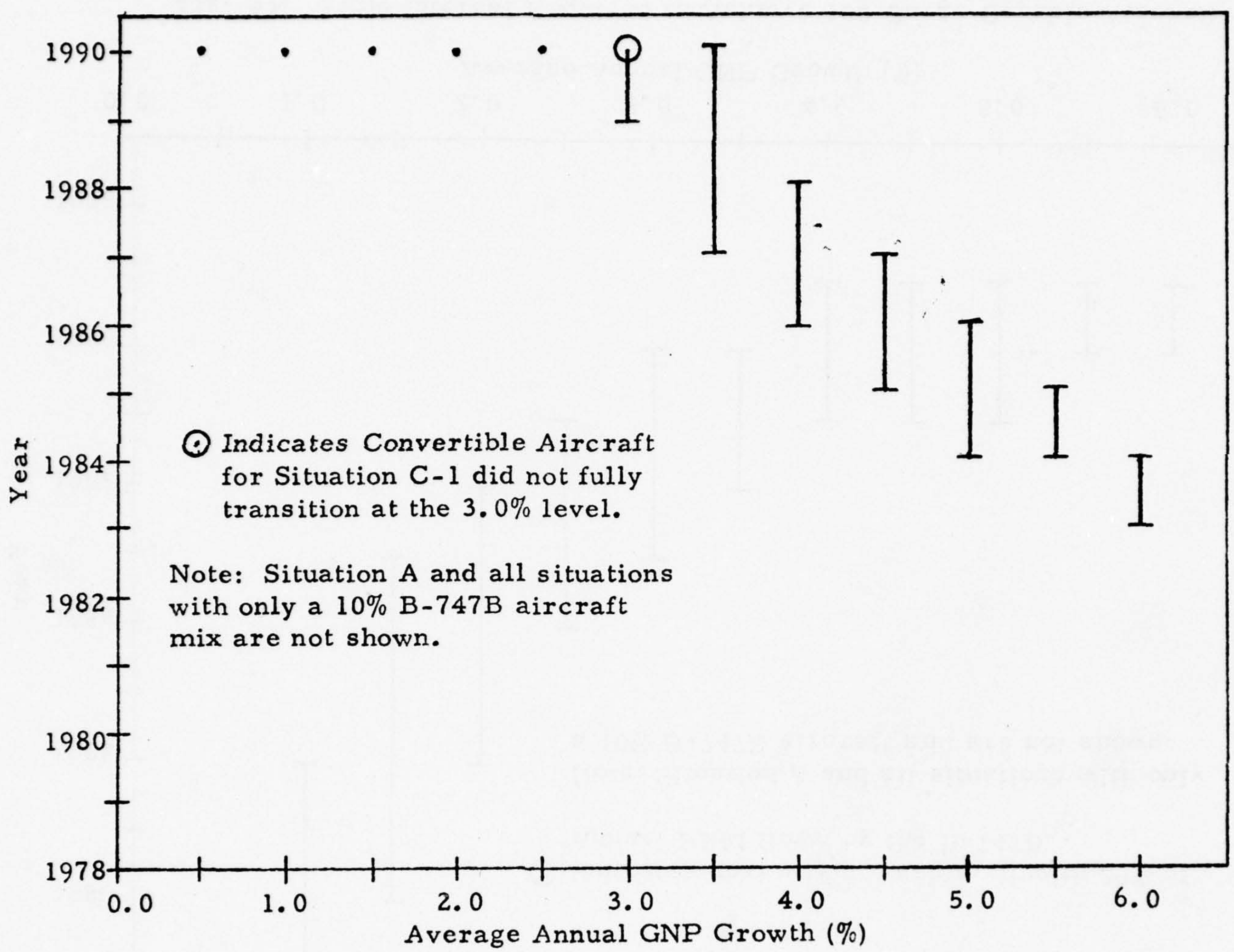

Fig. 42. Time Interval Required to Transition Convertible Aircraft to Freighter Mode

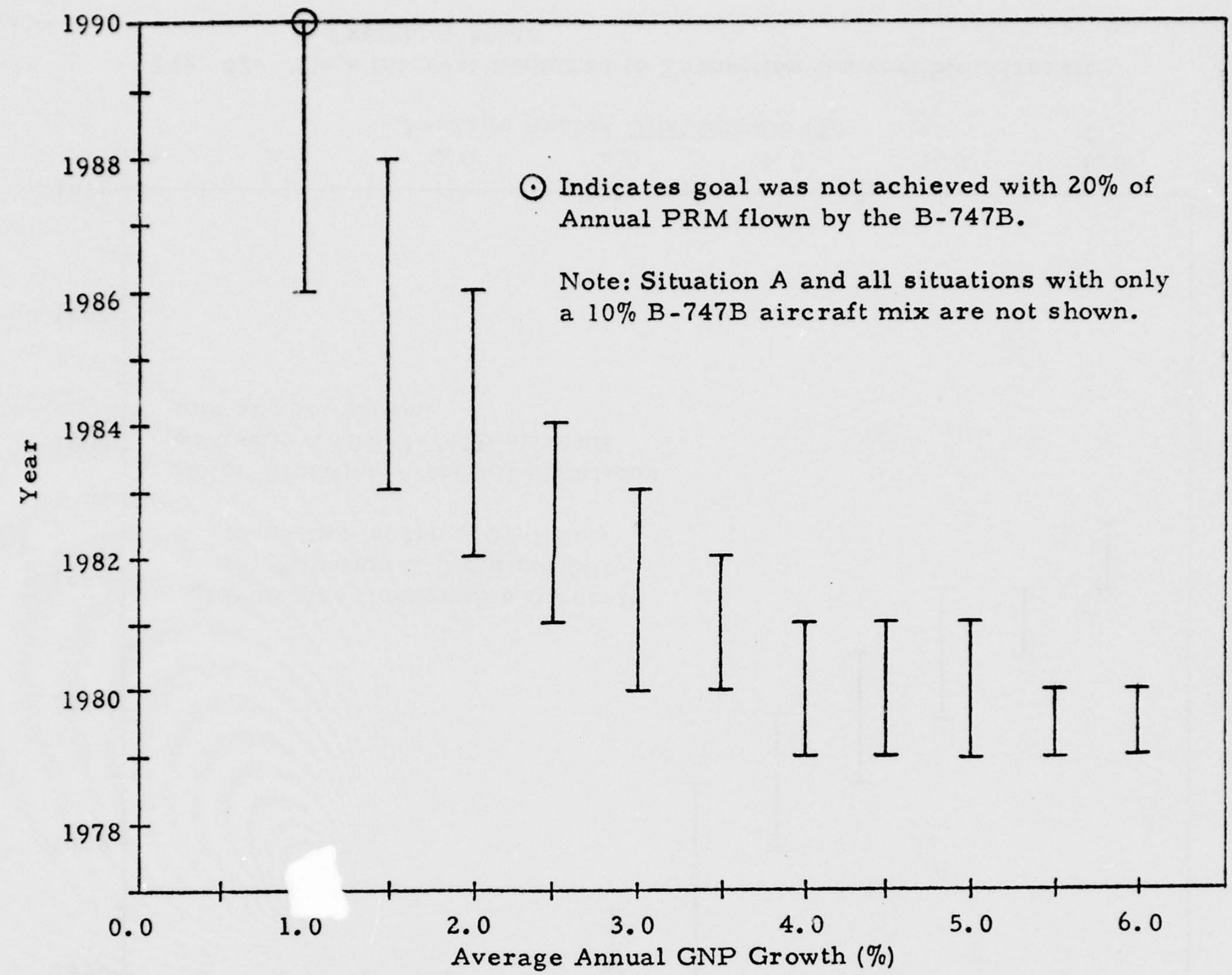

Fig. 43. Time Interval Required to Achieve 100 Cargo Capable Aircraft

Program Costs

To depict costs clearly, realignment of the various situations and associated market splits was necessary. Based on an incremental increase in the percentage of annual PRM serviced by B-747B aircraft in combination with the percentage serviced by B-727 aircraft in descending order, a comparison of discounted costs and reimbursements can be made easily. Figure 44 indicates a maximum cost occurs for Situation A while minimum costs occur for those situations and market splits with 10.0 percent of the annual PRM serviced by the B-747B. Also, as noted in Figure 43, a 10.0 and 20.0 percent market split for the B-747B at the 1.0 level is not comparable since the program goal was not achieved; hence, the figure indicates lower costs. Two significant points are highlighted by Figure 44. First, there is little difference between a 2.0 to 3.0 percent GNP growth. At a 2.0 percent GNP level, investment costs are time-phased over a longer period meaning a lower discount rate, as well as less operating costs. For a 3.0 percent GNP level, investment costs occur in the early years of the program plus associated operating costs. Further, the depressing effect of WB passenger aircraft lower hold capability dampens the transition of convertibles to freighters. Figure 45 shows the lower overall program costs associated with relatively high growth rates. A comparison of Figures 44 and 45 reveals a $78.9 million difference between the

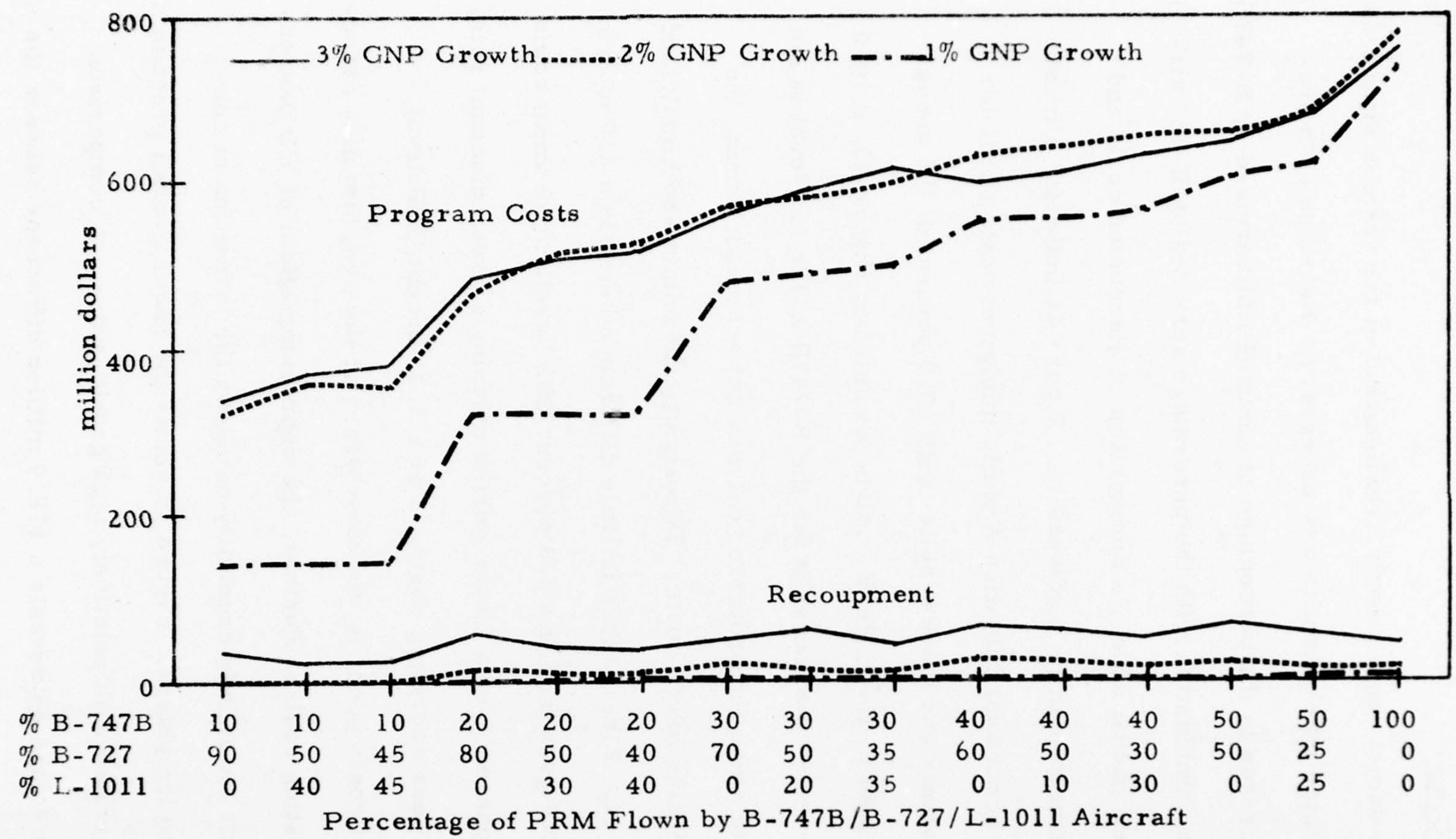

Fig. 44. Total Discounted Program Costs and Reimbursements for a 1.0, 2.0, and 3.0 Percent GNP Growth

least amount a program would cost between the 2.0 to 6.0 percent GNP level. Maximum costs range from $583.7 million to $685.2 million for 6.0 and 2.0 GNP growth levels, respectively (see Appendix S).

Air carrier reimbursements reduce program costs as outlined in Figure 44; however, at no time were reimbursements sufficient to fully recoup initial government investment costs. Even at the higher GNP levels, initial costs were not overcome through reimbursement. Figures 46 and 47 illustrate the total discounted net cost associated with a government sponsored program with a reimbursement feature. The least cost of $302.0 million occurs at a 6.0 percent GNP level for a 50-25-25 market split while the maximum cost of $665.3 million remains at the 2.0 percent GNP level.

VALIDATION

Each successive situation introduced to the computer model brought about a closer correspondence to the real world. Specifically, values for productivity of various aircraft used in the model were based on actual operating experience of the air carriers. The computer model was validated by comparing its results for Situation A with those achieved by the ATA. Specifically, the ATA has forecasted the number of seats required by 1990 based on an annual 5.0 percent growth in revenue passenger enplanements. Figure 46

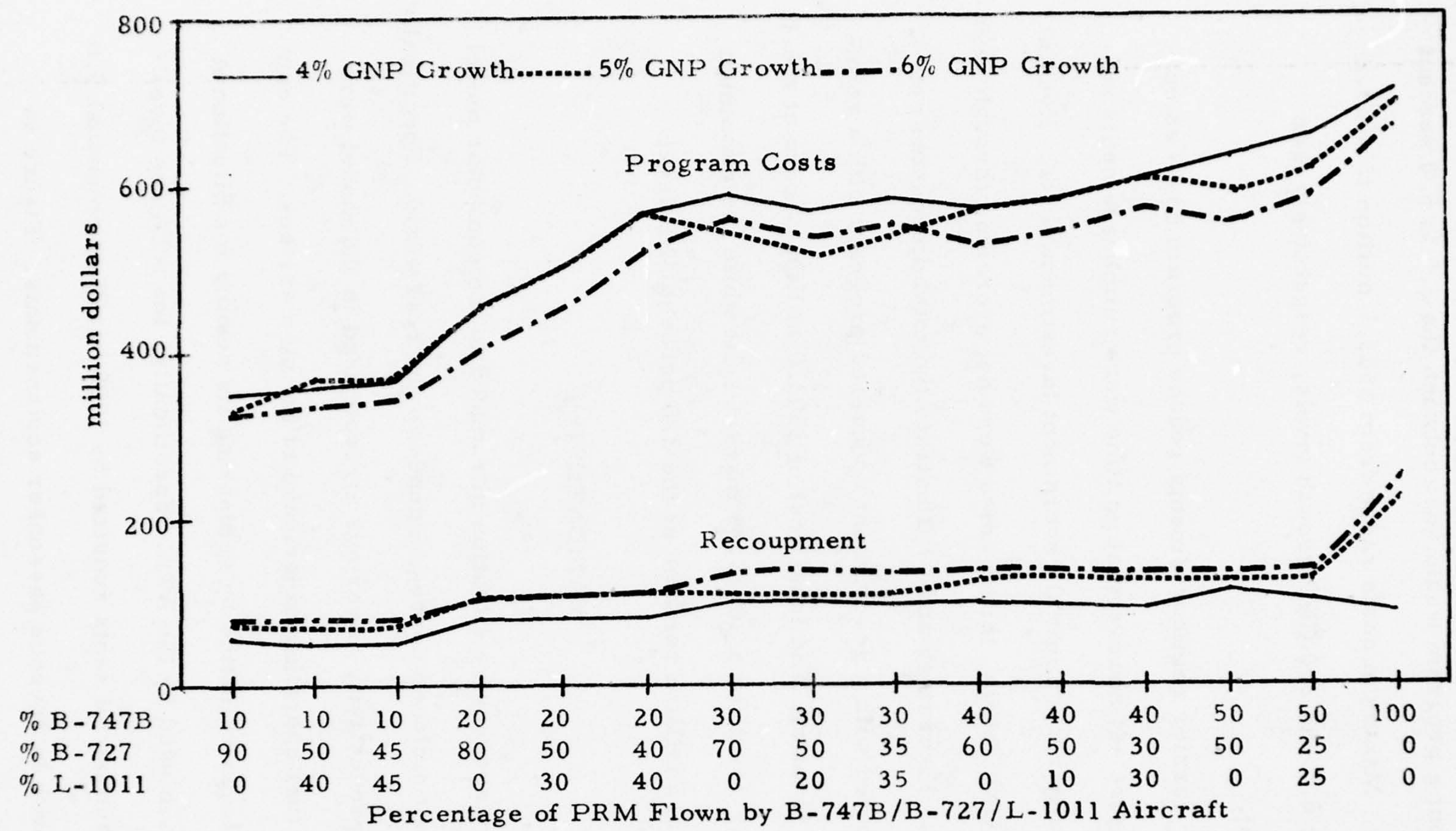

Fig. 45. Total Discounted Program Costs and Reimbursements for a 4.0, 5.0, and 6.0 Percent GNP Growth

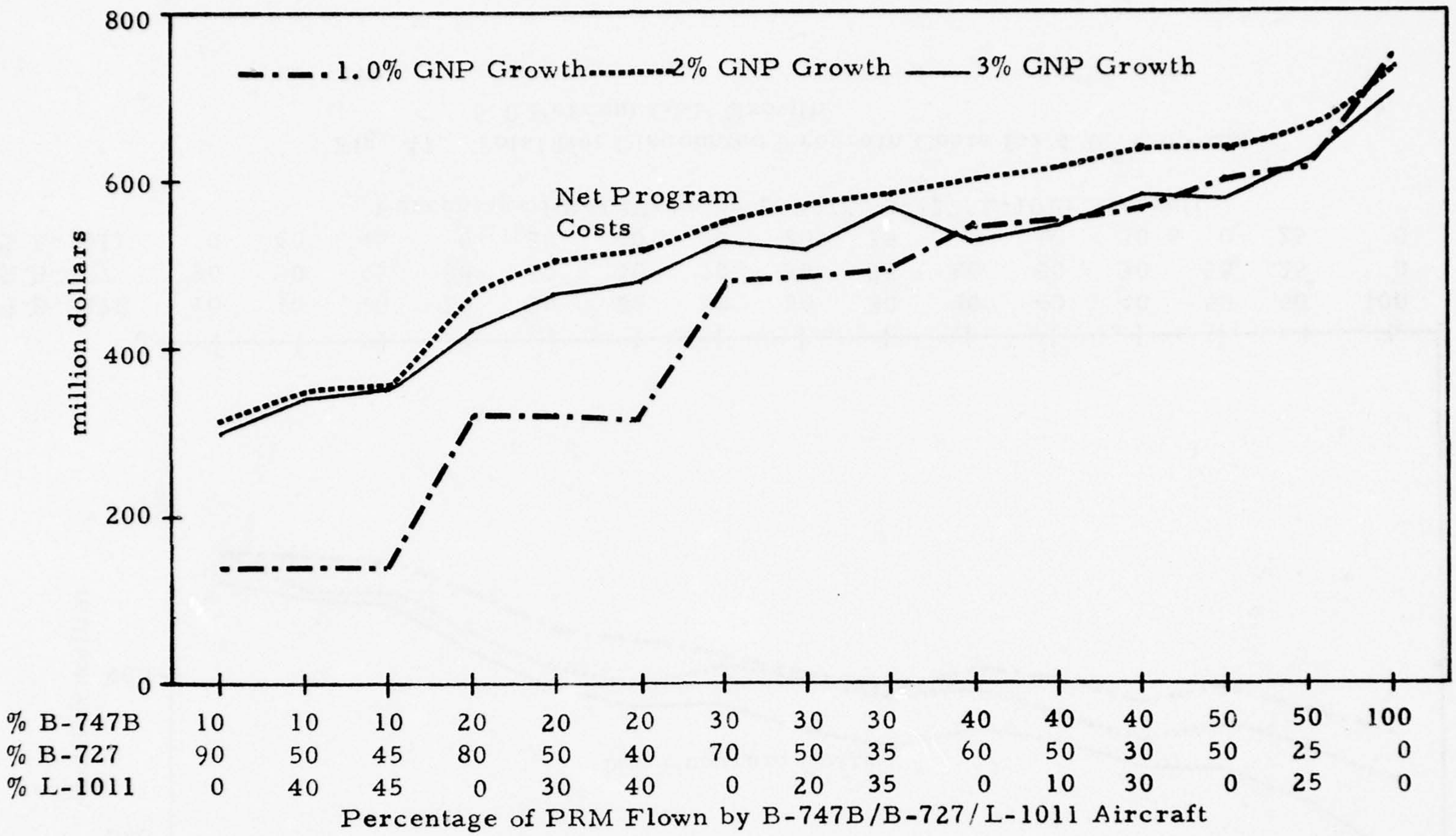

Fig. 46. Total Net Discounted Program Costs for 1.0, 2.0, and 3.0 Percent GNP Growth

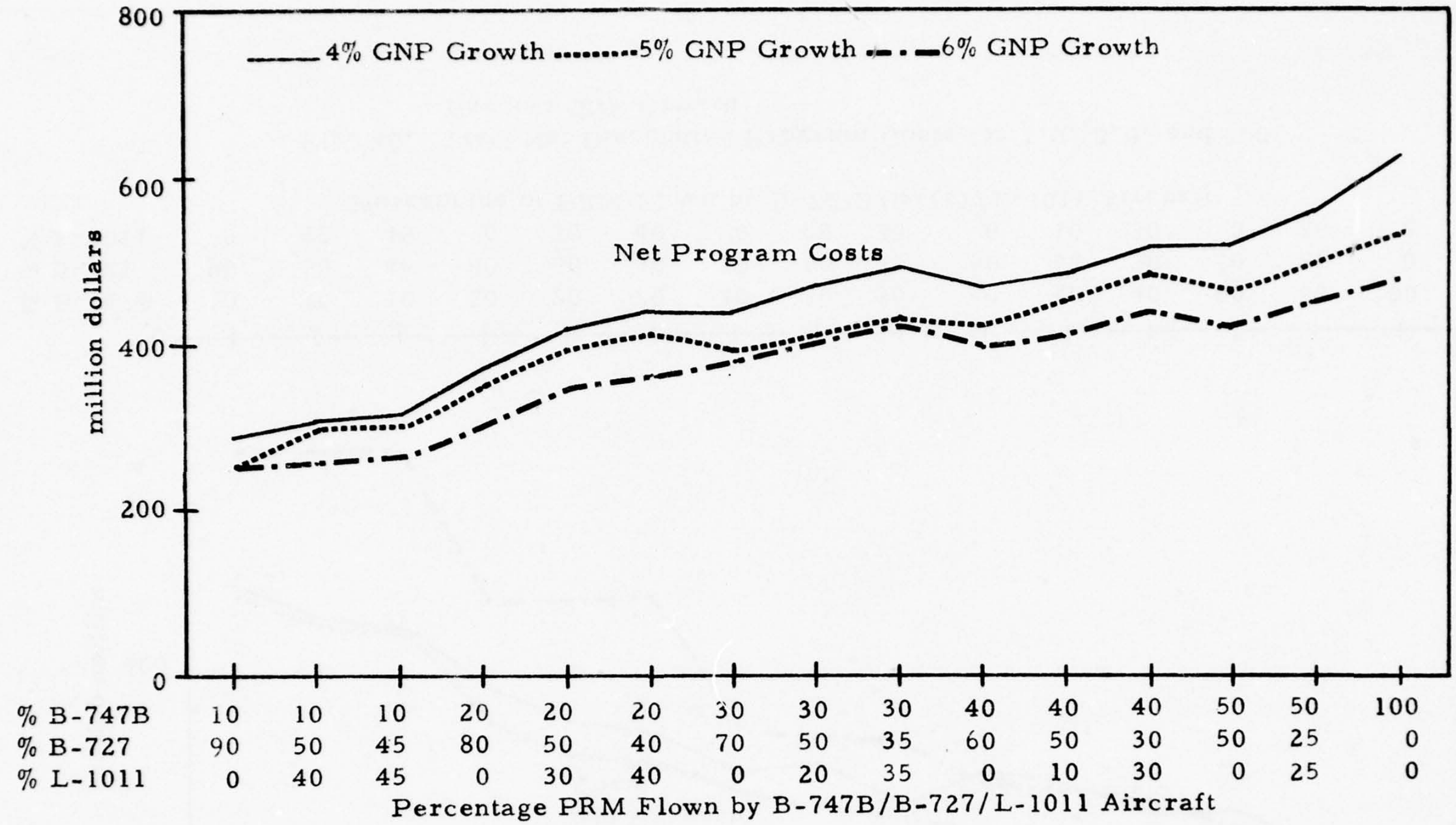

Fig. 47. Total Net Discounted Program Costs for 4.0, 5.0, and 6.0 Percent GNP Growth

compares the ATA forecast converted to B-747B airframes (423 seats per aircraft) with the researchers' computer model at the 1.5 percent GNP level. The ATA was projecting 239,540 seats needed to cope with new requirements. Further, the ATA estimated an attrition of 160,033 seats throughout the period based on an 18 year aircraft life (1:11). Since the scope of this thesis excluded consideration of aircraft attritioned out of the system, Figure 46 illustrates strictly equipment required to service growth only. Although industry forecasts vary depending on the source, the aircraft market is estimated at between $55--$66 billion by Boeing and $57 billion by Lockheed through the 1985 time frame (70:233). In the banking industry, bankers' estimates of capital requirements include an assumption that 730 new aircraft will be purchased by the trunk carriers and Pan American by 1985. And lastly, on a worldwide basis, the FAA has forecast a 55.0 percent increase in jet aircraft from 5,489 in 1975 to 8,458 in 1990 (45:29).

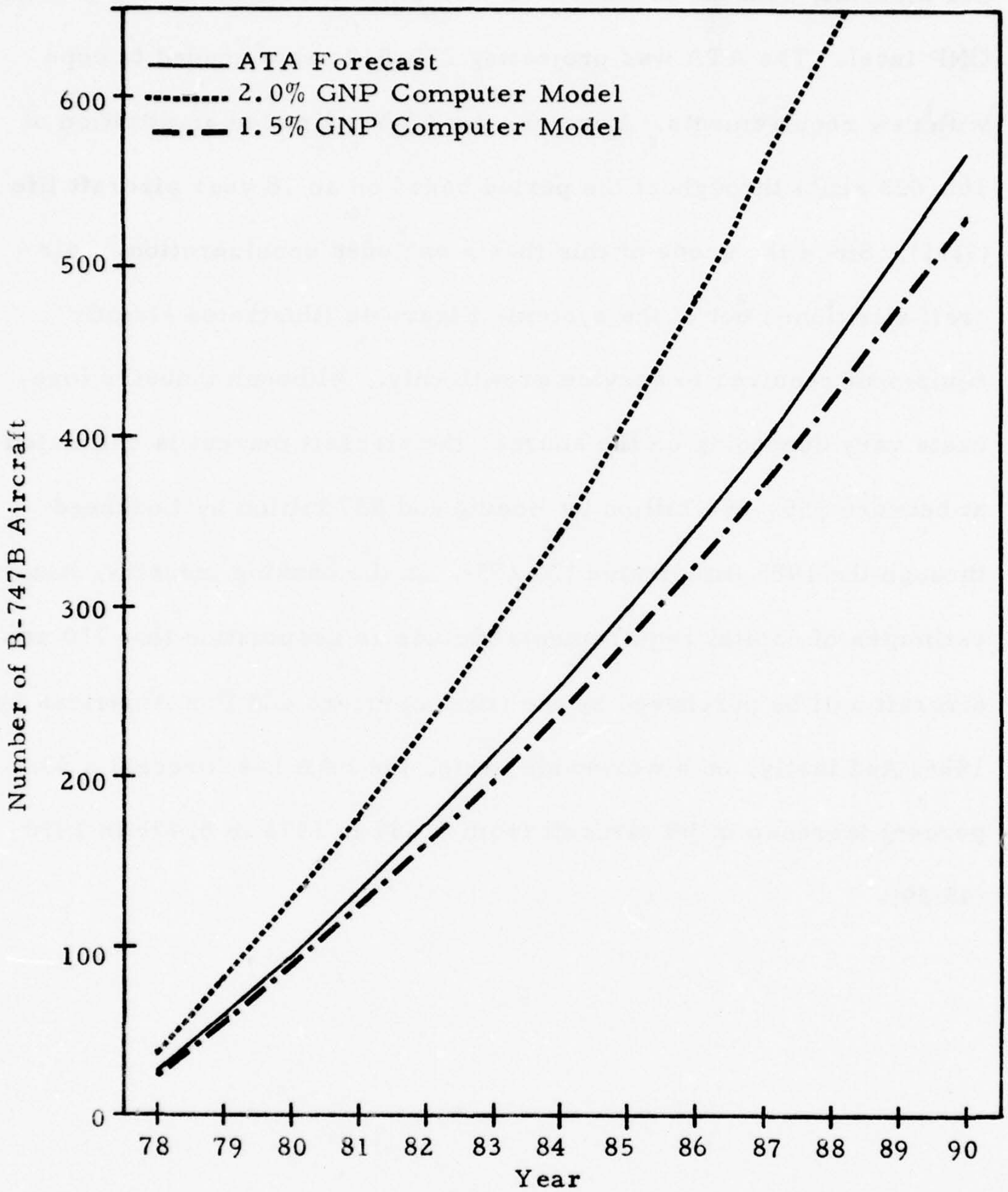

Fig. 48. Comparison of Computer Model Results and ATA Capital Requirements Forecast at 1.5 and 2.0 Percent Average Annual GNP Growth

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The computer model and associated parameters were constructed to highlight the subtle real world relationships which could conceivably impact on a government program to sponsor cargo capable convertible aircraft. If the reader disagrees with variables encompassed by the computer model, values input to achieve the results explained earlier, or conclusions that follow, the reader can adjust the variables and/or values in two ways: (1) an external forecast can be inserted in lieu of the log-linear equations contained in the main computer program, and (2) one or more variables relative to productivity of the aircraft selected as standards can be changed simultaneously. In the opinion of the researchers, the values used in the model represented the best conservative estimates of real world relationships that existed at the time the study was undertaken. Further, the reader is cautioned not to lose sight of the fact that the discounting technique permits comparisons to be made in constant base year dollars.[1]

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[1]A good example is Situation A. The discounted cash flow of reimbursement at a 3.0 percent average annual GNP growth is $49.1 million in base year 1978 dollars. In current year dollars, the same cash flow is $124.9 million.

CONCLUSIONS

Through the use of a computer model to examine the impact of national economic growth on the U.S. air passenger and cargo markets relative to a government sponsored convertible aircraft, the researchers concluded:

1. The time interval over which 100 cargo capable aircraft could be achieved varies with the level of sustained economic growth. Further, the time interval is significantly affected below the 3.5 percent GNP level depending on how U.S. air carriers equip their fleets to meet the demand for air transportation. Table VIII provides the earliest and latest years such a program could be achieved when a minimum of between 20 to 50 percent of annual PRM are flown by B-747B aircraft.

2. The time interval over which convertible aircraft would be transitioned to a freighter mode by air carriers is dependent on the level of sustained economic growth and air carriers' decision on the composition of their fleets. A minimum GNP growth level of between 3.0 to 3.5 percent is required to completely transition convertible aircraft to a freighter mode. This conclusion is predicated on the basis WB aircraft similar to the B-747B service between 20 to 50 percent of annual PRM generated. Table IX provides the earliest and latest years in which the time-phased transition process terminates.

Table VIII
Time Interval Required to Achieve Program Goal

Average Annual GNP Growth	Earliest Year	Latest Year
0.5	n/a	n/a
1.0	1986	*
1.5	1983	1988
2.0	1982	1986
2.5	1981	1984
3.0	1980	1983
3.5	1980	1982
4.0	1979	1981
4.5	1979	1981
5.0	1979	1981
5.5	1979	1980
6.0	1979	1980

*The goal is achieved by a 20-80-0 aircraft mix only.

Table IX
Time Interval Required to Transition Convertibles to a Freighter Mode

Average Annual GNP Growth	Earliest Year	Latest Year
0.5	n/a	n/a
1.0	n/a	n/a
1.5	n/a	n/a
2.0	n/a	n/a
2.5	n/a	n/a
3.0	1989	see footnote
3.5	1987	1990
4.0	1986	1988
4.5	1985	1987
5.0	1984	1986
5.5	1984	1985
6.0	1983	1984

*Figure 43 highlights the impact the L-1011 servicing a larger share of the annual air passenger market; namely, beginning with as little as a 5.0 percent change in air traffic serviced by the L-1011 vs the B-727, government sponsored convertibles are not completely transitioned until a 3.5 percent GNP growth level is achieved.

3. The total discounted cost of a government sponsored program to achieve 100 cargo capable aircraft is dependent on the aircraft mix selected by air carriers to service annual air traffic and the strength of the economy. The minimum discounted cost of such a program is $403.7 million dollars reaching a maximum of $685.2 million for a 6.0 and 2.0 percent average annual GNP growth, respectively. Table X provides the range of costs in relation to the state of the economy.

Table X
Total Discounted Program Costs

Average Annual GNP Growth (%)	Least Program Cost (million $)	Maximum Program Cost (million $)
1.0	318.0*	618.0
2.0	482.6	685.2
3.0	484.7	681.9
4.0	456.2	658.1
5.0	448.2	615.7
6.0	403.7	583.7

*Program goal not achieved.

4. Based on Table X relating to program costs, the researchers concluded air carriers' decisions on equipping their fleets can result in an increase in government program costs by as much as

$202.6 million between a 2.0 and 3.0 average annual growth.

5. A fluctuation between an average annual growth of 2.0 to 3.0 percent will not significantly increase or decrease program costs.

6. Air carrier reimbursement at the rate of 0.5 percent of gross revenue yields per cargo ton-mile below a 3.0 percent GNP growth is extremely small in relation to initial government sponsorship costs. Further, reimbursement would be insufficient to cover initial government costs for all GNP growth levels examined. Table XI provides the range of total discounted net program costs for different levels of economic growth.

Table XI
Total Net Discounted Program Costs

Average Annual GNP Growth (%)	Least Program Cost (million $)	Maximum Program Cost (million $)
1.0	318.0*	616.1
2.0	468.5	665.3
3.0	426.6	624.9
4.0	372.7	557.7
5.0	350.9	494.3
6.0	302.0	450.0

*Program goal not achieved.

7. Without a government program, a total of between 39 to 60 WB long range freighter aircraft will enter the U.S. air carrier fleet by 1990, providing a 2.0 percent annual GNP growth is maintained. Over the same time period, a 3.0 percent average annual GNP growth with yield between 74 to 125 WB long range freighter aircraft.

RECOMMENDATIONS

This study represented a research effort designed to examine the sensitivity of costs associated with a government sponsored program designed to achieve 100 cargo capable aircraft. Further study is recommended in the area of examining the real utility value of one ton of cargo airlifted to meet emergency wartime requirements. The study should be classified appropriately and take into consideration current intelligence estimates, the cost of prepositioning war reserve material, combat readiness, and several other factors. The thrust of the effort should consider the impact of the inability to deploy sufficient U.S. conventional firepower within specified closure times outlined in JCS and/or Air Force planning documents.

Once a set of values based on supportable rationale have been achieved, an attempt should be made to quantify the values in monetary terms. Used in conjunction with a model similar to the one constructed for this thesis, the relative benefits of airlift should be compared with costs of either sufficient military airlift or a

government sponsored program to ensure that a viable civilian air cargo capability exists. The end result of a combination of studies in these areas combined with the efforts of military decision makers could conceivably form the framework of a comprehensive document justifying the criticality of airlift to the Congress from a cost/benefit standpoint. Such an approach could possibly add impetus to congressional funding and subsequent resolution of the strategic airlift deficit.

APPENDIX A

LISTING OF AIR CARRIERS

The following is a listing of Certificated Route and Supplemental Air Carriers possessing fixed wing aircraft as of December 31, 1976 (71:19-93):

DOMESTIC PASSENGER/CARGO CARRIERS

Trunk Carriers

*American
*Braniff
*Continental (includes Air Micronesia)
Delta
*Eastern
National
*Northwest
*Trans World
*United
*Western

Intra-Alaska Carriers

*Alaska Airlines
Kodiak-Western Alaska Airlines
Munz Northern
*Reeve Aleutian
*Wien Air Alaska

Intra-Hawaii Carriers

Aloha
*Hawaiian

Local Service Carriers

Allegheny
Frontier
Hughes Air West
North Central
Ozark
Piedmont Aviation
Southern
Texas International

Other/Regional

Air New England
Aspen
Wright

INTERNATIONAL AND TERRITORIAL PASSENGER/CARGO

*Pan American

ALL CARGO CARRIERS

*Airlift International
*Flying Tiger
*Seaboard World

SUPPLEMENTAL AIR CARRIERS

*Capitol International Airways
*Evergreen International Airlines
McCulloch International Airlines
Modern Air Transport
*Overseas National Airlines
*Trans International Airlines
*World Airways

*CRAF program participant as detailed by HQ MAC/XPW, Monthly Civil Reserve Air Fleet (CRAF) Capability Summary, dated 1 June 1977 (see Appendix B to this thesis).

APPENDIX B

MONTHLY CIVIL RESERVE AIR
FLEET (CRAF) CAPABILITY SUMMARY,
1 JUNE 1977

MONTHLY CIVIL RESERVE AIR FLEET (CRAF) CAPABILITY SUMMARY

SOURCE: HQ MAC/XPRC

AS OF: 1 JUNE 1976

CAPABILITY TYPE	STAGES II	STAGES III
DOMESTIC CARGO CAPABILITY (BTM)	1.351	1.351
DOMESTIC PASSENGER CAPABILITY (BPM)		3.985
ALASKAN CARGO CAPABILITY (BTM)	.030	.313
SHORT-RANGE CARGO CAPABILITY (BTM)		1.273

AIRLINE AND CRAF STAGE	WORLD (WOA) I	II	III	PASSENGER I	II	III	CONVERTIBLE I	II	III	FREIGHTER I	II	III	TOTAL EACH STAGE I	II	III
TOTAL (PAX)				14	26	91							14	26	91
TOTAL (CARGO)	2	5	7				41	53	77	7	20	67	48	73	144
GRAND TOTAL	2	5	7				41	53	77	7	20	67	62	99	235

CAPABILITY TYPE	STAGES I	II	III
LONG-RANGE CARGO CAPABILITY (BTM)	4.725	6.806	12.370
WIDE-BODY PASSENGER AIRCRAFT LOWER LOBE CARGO CAPABILITY (BTM)	.294	.541	1.529
TOTAL LONG-RANGE CARGO CAPABILITY (BTM)	5.019	7.347	13.899
CONVERTIBLE PASSENGER CAPABILITY (BPM)	18.292	23.616	34.207
LONG-RANGE PAX CAPABILITY (BPM)	9.974	18.303	63.226
SUMMARY OF SEGMENTS			
DOMESTIC		27	38
ALASKAN		4	12
SHORT-RANGE INTERNATIONAL			35
LONG-RANGE INTERNATIONAL (PAX)	14	26	91
LONG-RANGE INTERNATIONAL (CARGO)	48	73	144
TOTAL CRAF	62	130	320

REMARKS

CARRIER	NO	TYPE ACFT	REG NO	ACTION
WOA	1	B727-173C	693WA	Add SRI Cargo
WOA	2	B727-173C	690WA, 692WA	Drop SRI Cargo

NOTES

- * Indicates supplemental carriers
- \# Call contract.
- Capability reflected in millions of ton or passenger miles (BTM or BPM) per day
- Cargo capability based on CRAF wartime planning payload (AFM 76-2)
- ○ Indicates changes since previous capability summary

MAC FORM 0-312 PREVIOUS EDITIONS ARE OBSOLETE

APPENDIX C

PASSENGER REVENUE MILES FLOWN BY
UNITED STATES CERTIFICATE ROUTE AIR CARRIER,
1950 TO 1956

Passenger Revenue Miles Flown By
United States Certificated Route Air Carriers,
1950 to 1976

Year	Certificated Route Air Carriers			
	Domestic Service		International Service	
	Scheduled (millions)	Nonscheduled[1] (millions)	Scheduled (millions)	Nonscheduled (millions)
(1)	(2)	(3)	(4)	(5)
1950	8,007	-	2,214	-
1951	10,590	105	2,614	141
1952	12,559	96	3,065	140
1953	14,794	84	3,451	157
1954	16,802	162	3,810	200
1955	19,852	196	4,499	172
1956	22,399	507	5,226	520
1957	25,379	905	5,882	619
1958	25,376	690	6,124	766
1959	29,308	524	7,064	875
1960	30,567	529	8,306	649
1961	31,062	545	8,769	1,402
1962	33,623	662	10,138	1,817
1963	38,457	559	11,905	2,295
1964	44,141	905	14,353	2,400
1965	51,887	1,338	16,789	3,201
1966	60,591	2,494	19,298	5,759
1967	75,487	4,034	23,259	8,997
1968	87,508	4,604	26,451	11,475
1969	102,717	4,502	22,703	12,782
1970	104,156	4,295	27,563	12,132
1971	106,438	3,365	29,219	10,282
1972	118,138	3,682	34,268	7,927
1973	126,317	4,133	35,640	8,262
1974	129,732	3,936	33,186	7,197
1975	131,728	4,271	31,082	6,243
1976	145,271	6,108	33,717	6,746

[1]Passenger Revenue miles have been estimated from Passenger Revenue Ton-miles for years 1951 to 1962 by equating 10 Passenger Revenue Miles to 1 Passenger Revenue Ton-mile (1 passenger = 200 lbs).

Sources: Columns 2 and 4: FAA Statistical Handbook of Aviation, 1965, Tables 8.19 and 8.20 for 1950 to 1959 (30:151-152); FAA Statistical Handbook of Aviation 1968, Tables 8.19 and 8.20 for 1960

to 1967 (32:187); FAA Statistical Handbook of Aviation, 1975, Tables 6.18 and 6.19 for 1968 to 1975 (23:78-79); Air Carrier Traffic Statistics, Part I for 1976 (13:4, 14).

Columns 3 and 5: Handbook of Airline Statistics, Part II, Table 13 for 1951 to 1962 (14:21); FAA Statistical Handbook of Aviation 1965, Table 8.3 for 1963 and 1964 (30:138); FAA Statistical Handbook of Aviation 1967, Table 8.3 for 1965 (31:138); FAA Statistical Handbook of Aviation 1968, Table 8.3 for 1966 and 1967 (32:173); FAA Statistical Handbook of Aviation 1970, Table 6.3 for 1968 and 1969 (33:126); FAA Statistical Handbook of Aviation 1972, Table 6.3 for 1970 and 1971 (34:137); FAA Statistical Handbook of Aviation, 1973, Table 6.3 for 1972 and 1973 (35: 76); FAA Statistical Handbook of Aviation 1975, Table 6.3 for 1974 and 1975 (23: 73); Air Carrier Traffic Statistics, Part I for 1976 (13:4, 14).

APPENDIX D

CERTIFICATED ROUTE AIR CARRIER DOMESTIC MAIL AND AIR CARGO OPERATIONS (1950-1976)

Certificated Route Air Carrier Domestic Mail and
Air Cargo Operations (Thousands of Revenue Cargo Ton-Miles)

Year	Passenger/Cargo Carriers				All-Cargo Carriers	
	Air Cargo		Scheduled Service Mail		Air Cargo	
	Scheduled Service	Nonscheduled Service			Scheduled Service	Nonscheduled Service
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1950	152,223	2,537	47,740	-	58,420	12,995
1951	144,790	1,348	64,734	-	72,327	25,037
1952	162,047	553	70,443	-	81,829	4,618
1953	179,063	943	74,106	-	74,579	8,762
1954	189,765	1,539	82,768	-	58,091	4,264
1955	229,966	6,388	88,751	282	88,802	13,497
1956	247,255	18,069	94,523	1,153	103,911	28,508
1957	268,791	4,979	100,218	1,835	127,286	106,024
1958	294,018	2,898	107,018	1,002	92,716	115,868
1959	344,728	3,192	120,308	743	105,487	134,702
1960	386,933	2,505	135,923	907	89,566	132,696
1961	454,142	1,809	150,452	669	79,040	180,478
1962	554,599	2,974	166,801	321	82,233	348,379
1963	603,726	5,367	174,439	1,009	110,844	204,581
1964	743,963	13,911	189,782	1,847	149,812	195,036
1965	943,128	53,971	225,992	2,260	168,837	275,714
1966	1,108,691	86,060	291,277	2,701	192,785	303,043
1967	1,314,409	86,106	406,300	2,297	183,819	319,714
1968	1,579,091	64,657	564,186	3,187	195,581	180,978
1969	1,916,472	180,728	800,814	5,535	209,588	184,524
1970	1,965,904	37,289	705,666	9,136	249,590	42,555
1971	2,012,818	128,832	696,780	10,792	264,913	35,059

Year	Passenger/Cargo Carriers				All-Cargo Carriers	
	Air Cargo		Scheduled Service Mail		Air Cargo	
	Scheduled Service	Nonscheduled Service			Scheduled Service	Nonscheduled Service
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1972	2,240,039	104,800	676,062	9,526	326,722	42,300
1973	2,453,517	16,717	658,287	28,340	468,076	37,111
1974	2,421,926	9,733	667,577	24,405	466,234	42,182
1975	2,331,176	8,847	665,493	17,780	415,657	30,431
1976	2,474,884	17,952	707,660	10,895	434,373	17,999

Sources: Columns 2, 3, 6 and 7: FAA Statistical Handbook of Aviation 1965, Table 8.14 for 1950 to 1959 (30:146); FAA Statistical Handbook of Aviation 1968, Table 8.14 for 1960 to 1967 (32:184); FAA Statistical Handbook of Aviation, Calendar Year 1975, Table 6.14 for 1968 to 1975 (23:77); Air Carrier Traffic Statistics, Dec. 1976, Part I for 1976 (13:5, 13).

Column 4: FAA Statistical Handbook of Aviation 1965, Table 8.15 for 1950 to 1959 (30:147); FAA Statistical Handbook of Aviation 1968, Table 8.15 for 1960 to 1967 (32:185); FAA Statistical Handbook of Aviation, Calendar Year 1975, Table 6.10 for 1968 to 1975 (23:75); Air Carrier Traffic Statistics, Dec. 1976, Part I for 1976 (13:5).

Column 5: FAA Statistical Handbook of Aviation 1965, Table 8.12 for 1950 to 1959 (32:145); FAA Statistical Handbook of Aviation 1968, Table 8.12 for 1960 to 1967 (32:181); FAA Statistical Handbook of Aviation, Calendar Year 1975, Table 6.12 for 1968 to 1975 (23: 76); Air Carrier Traffic Statistics, Dec. 1976, Part I Table for 1976 (13:13).

APPENDIX E

CERTIFICATED ROUTE AIR CARRIER
INTERNATIONAL MAIL AND AIR CARGO
OPERATIONS (1950-1976)

Certificated Route Air Carrier International Mail
and Air Cargo Operations
(thousands of Revenue Cargo-Ton Miles)

Year	Scheduled Service			Passenger/Cargo and All-Cargo Carrier Freight Non-Scheduled Service
	Passenger/Cargo Carriers		All-Cargo Carriers	
	Air Cargo	Mail	Mail and Air Cargo	
(1)	(2)	(3)	(4)	(5)
1950	60,588	26,228	---[1]	---[1]
1951	71,665	27,089	6,251	2,846
1952	75,706	28,201	10,665	3,894
1953	79,579	31,630	14,233	1,969
1954	86,840	43,554	18,703	9,473
1955	96,378	61,233	19,179	49,123
1956	115,172	64,355	38,045	83,382
1957	128,239	66,894	29,478	55,926
1958	133,958	75,635	31,498	56,483
1959	159,349	81,997	42,205	68,535
1960	191,585	103,355	44,295	42,238
1961	217,164	144,903	56,273	46,784
1962	264,729	172,017	77,738	68,896
1963	296,404	181,257	97,507	38,830
1964	394,681	180,991	101,014	45,029
1965	597,324	254,093	122,017	120,180
1966	721,609	452,635	141,543	510,141
1967	796,964	560,402	171,001	682,473
1968	927,250	679,357	229,111	716,197
1969	936,554	463,099	368,320	794,283
1970	942,008	548,845	573,251	268,040
1971	1,009,785	456,683	668,044	678,084
1972	1,114,104	371,656	767,566	746,954
1973	1,238,584	361,440	837,982	392,223
1974	1,339,056	347,762	866,407	309,443
1975	1,259,439	311,707	903,247	255,597
1976	1,380,625	291,682	921,984	266,585

[1]Not organized until 1951.

Sources: Columns 2 and 3: FAA Statistical Handbook of Aviation, 1965, Table 8.16 for 1950 to 1959 (30:149); FAA Statistical Handbook of Aviation, 1968, Table 8.16 for 1960 to 1967 (32:185);

FAA Statistical Handbook of Aviation, 1975, Table 6.16 for 1968 to 1975 (23:77); Air Carrier Traffic Statistics, Dec. 1976, Part I for 1976 (13:15).

Column 4: FAA Statistical Handbook of Aviation, 1965, Table 8.13 for 1950 to 1959 (30:146); FAA Statistical Handbook of Aviation, 1968, Table 8.13 for 1960 to 1967 (32:181); FAA Statistical Handbook of Aviation, 1975, Table 6.13 for 1968 to 1975 (23:76); Air Carrier Traffic Statistics, Dec. 1976, Part I for 1976 (13:16).

Column 5: Handbook of Airline Statistics, 1973 Edition, Part II, Table 35 for 1951 to 1971 (14:43); FAA Statistical Handbook of Aviation, 1973, Table 6.3 for 1972 and 1973 (35:76); FAA Statistical Handbook of Aviation, 1975, Table 6.13 for 1974 and 1975 (23:76); Air Carrier Traffic Statistics, Dec. 1976, Part I for 1976 (13:14).

APPENDIX F

SUPPLEMENTAL CARRIER OPERATIONS
(1950-1976)

Supplemental Carrier Operations

Year	Passenger Revenue Ton-Miles* (thousands)		Revenue Cargo Ton-Miles* (thousands)	
	Domestic Service	International Service	Domestic Service	International Service
(1)	(2)	(3)	(4)	(5)
1950	58,365	17,115	13,113	19,837
1951	78,234	26,443	17,686	62,703
1952	93,939	28,257	10,255	68,626
1953	100,075	34,867	18,089	57,190
1954	93,337	34,160	23,709	28,378
1955	118,944	56,166	40,557	34,044
1956	67,567	26,165	58,806	51,571
1957	42,738	31,534	47,175	39,532
1958	55,385	58,935	61,310	27,886
1959	61,335	93,189	63,368	21,202
1960	60,069	149,127	111,970	8,429
1961	67,489	95,504	113,942	44,918
1962	51,194	138,142	115,171	99,506
1963	33,449	119,532	170,661	48,076
1964	41,008	107,036	185,142	82,585
1965	46,942	199,505	219,780	77,821
1966	57,393	352,131	253,790	171,303
1967	70,883	516,956	264,317	177,746
1968	162,030	725,055	305,057	136,981
1969	111,830	1,003,259	255,202	192,783
1970	105,678	923,195	285,419	106,021
1971	91,397	965,968	305,605	195,632
1972	128,129	876,839	258,846	197,933
1973	196,764.1	818,424.5	291,584	112,033
1974	176,765.7	724,536.7	279,986	85,798
1975	86,842.8	602,615.5	261,847	100,718
1976	92,027	727,879	237,148	146,985

*Shown for illustration only, actual values used in the model were the total Passenger Revenue Miles flown by Supplemental Carriers, 10 revenue passenger miles equal 1 revenue passenger ton-mile approximately.

Sources: Columns 2 and 3: Handbook of Airline Statistics, 1973 edition, Part II Table 13 for 1950 to 1972 (14:21); Air Carrier Traffic Statistics, December 1974, Part III, page 93 for 1973 and 1974 (15:93). Air Carrier Traffic Statistics, Dec. 1976, Part III, page 91 for 1975 and 1976 (13:91).

Columns 4 and 5: Handbook of Airline Statistics, 1973 Edition, Part II, Table 35 for 1950 to 1972 (14:43); FAA Statistical Handbook of Aviation, Calendar Year 1975, Table 6.26 for 1973 to 1975 (23:82); Air Carrier Traffic Statistics, Dec. 1976, Part III, Page 91 for 1976 (13:91).

APPENDIX G

AIR CARRIER OPERATIONS
(1950-1976)

Air Carrier Operations (1950-1976)

Year	Revenue Passenger Miles Flown (millions)				Revenue Cargo Ton-Miles Flown (millions)			
	Certificated Route Air Carriers		Supplemental Air Carriers		Certificated Route Air Carriers		Supplemental Air Carriers	
	Scheduled	Nonscheduled		Total	Scheduled	Nonscheduled		Total
1950	10,220.7	-	754.8	10,975.5	345.2	15.5	33.0	393.7
1951	13,203.5	245.2	1,046.8	14,495.5	386.9	29.2	80.4	496.5
1952	15,624.3	236.2	1,222.0	17,082.5	428.9	9.1	78.9	516.9
1953	18,244.7	241.4	1,256.9	19,743.0	453.2	11.7	75.3	540.2
1954	20,612.8	361.8	1,243.0	22,217.6	479.7	15.3	52.1	547.1
1955	24,351.0	368.1	1,395.7	26,114.8	584.6	69.0	74.6	728.2
1956	27,624.8	1,027.2	1,004.0	29,656.0	664.4	130.0	110.4	904.8
1957	31,260.8	1,524.5	767.3	33,552.6	722.7	166.9	86.7	976.4
1958	31,499.4	1,456.3	1,153.0	34,108.7	735.9	175.2	89.2	1,000.3
1959	36,371.8	1,399.1	1,629.6	39,400.5	854.8	206.4	84.6	1,145.8
1960	38,862.8	1,178.1	2,207.6	42,258.5	952.6	177.4	120.4	1,250.4
1961	39,830.8	1,947.6	1,543.0	43,321.4	1,102.6	229.1	158.9	1,490.6
1962	43,760.4	2,478.8	1,869.7	48,108.9	1,318.4	420.2	214.7	1,953.3
1963	50,362.0	2,854.4	1,547.4	54,763.8	1,465.2	248.8	218.7	1,932.7
1964	58,493.7	3,732.5	1,502.0	63,729.2	1,762.1	254.0	267.7	2,283.8
1965	68,676.4	4,539.4	2,489.2	75,705.0	2,313.7	449.9	297.6	3,061.2
1966	79,889.2	8,253.5	4,125.4	92,268.1	2,911.2	899.2	425.1	4,235.5
1967	98,746.6	13,031.9	5,997.2	117,775.7	3,435.2	1,088.3	442.1	4,965.6
1968	113,958.3	16,079.0	8,886.0	138,923.3	4,173.3	961.8	446.5	5,581.6
1969	125,420.1	17,284.1	11,145.0	153,849.2	4,699.5	1,159.5	448.9	6,307.9
1970	131,710.0	16,427.4	10,289.0	158,435.6	4,994.4	347.9	391.4	5,733.7
1971	135,657.7	13,647.6	10.573.0	159,878.3	5,119.8	842.0	501.2	6,463.0
1972	152,406.3	11,609.0	9,987.0	174,002.3	5,505.6	894.1	456.8	6,856.5
1973	161,957.3	12,395.1	11,790.0	186,142.4	6,046.2	446.1	403.6	6,895.9

Year	Revenue Passenger Miles Flown (millions)				Revenue Cargo Ton-Miles Flown (millions)			
	Certificated Route Air Carriers		Supplemental Air Carriers	Total	Certificated Route Air Carriers		Supplemental Air Carriers	Total
	Scheduled	Nonscheduled			Scheduled	Nonscheduled		
1974	162,918.6	11,133.2	10,862.0	184,913.8	6,133.3	361.4	365.8	6,860.5
1975	162,810.0	10,513.7	8,759.3	182,083.1	5,904.4	294.9	362.6	6,561.9
1976	178,987.5	12,853.9	8,199.1	200,040.5	6,222.3	302.5	384.1	6,908.9

Source: Summation of traffic data outlined in Appendices C, D, E, and F.

APPENDIX H

GROSS NATIONAL PRODUCT
(1950-1976)

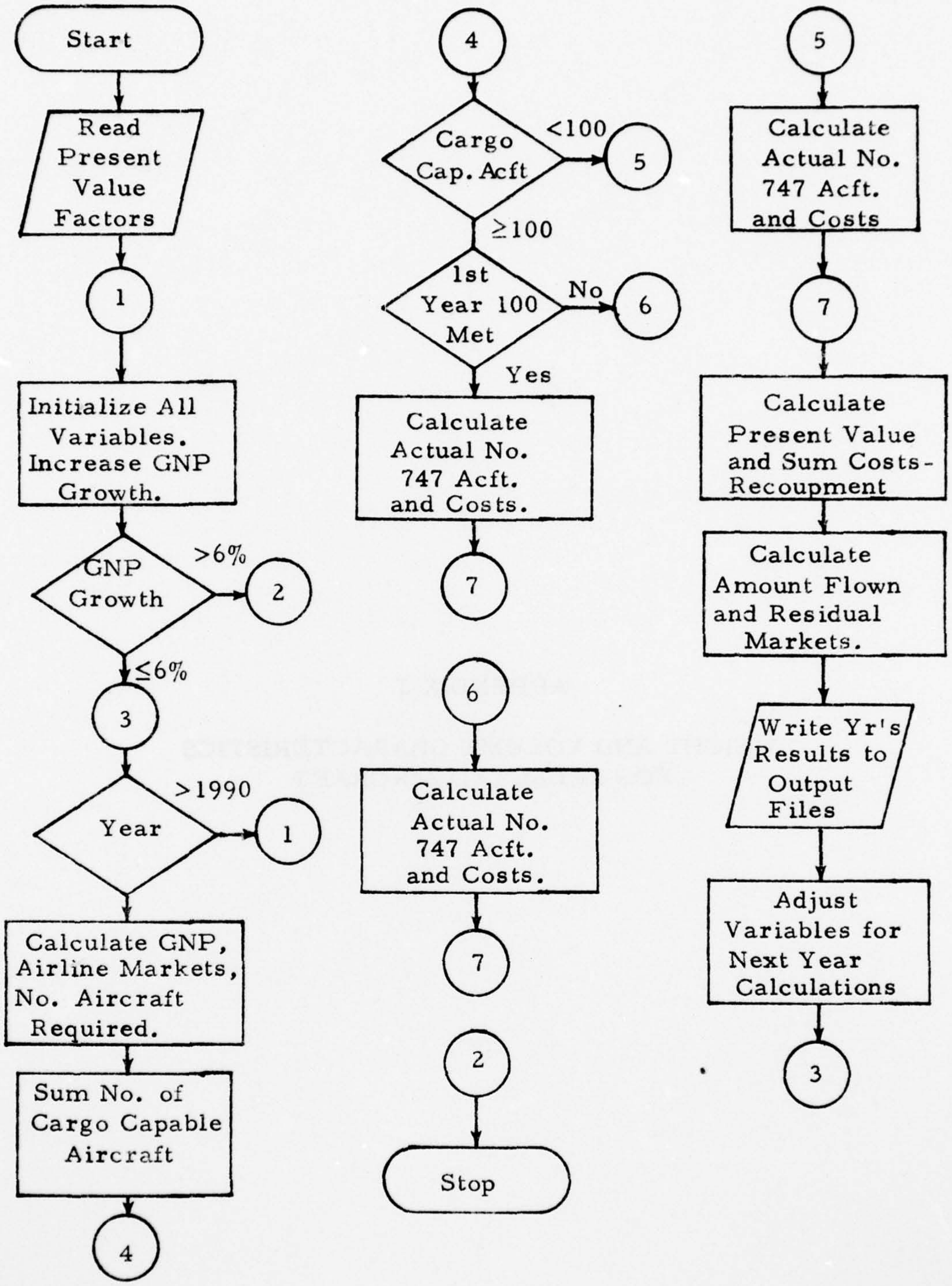
GNP (1950-1976)

Year	GNP (Billion) Current Dollars	% Change Current GNP	GNP (Billion 1972) Constant $	% Change Constant GNP
1950	286.2	9.85	533.5	8.02
1951	330.2	13.32	576.5	7.46
1952	347.2	4.90	598.5	3.68
1953	366.1	5.16	621.8	3.75
1954	366.3	0.05	613.7	-1.32
1955	399.3	8.26	654.8	6.28
1956	420.7	5.09	668.8	2.09
1957	442.8	4.99	680.9	1.78
1958	448.9	1.36	679.5	-0.21
1959	486.5	7.73	720.4	5.68
1960	506.0	3.85	736.8	2.23
1961	523.3	3.31	755.3	2.45
1962	563.8	7.18	799.1	5.48
1963	594.7	5.20	830.7	3.80
1964	635.7	6.45	874.4	5.00
1965	688.1	7.62	925.9	5.56
1966	753.0	8.62	981.0	5.62
1967	796.3	5.44	1007.7	2.65
1968	868.5	8.31	1051.8	4.19
1969	935.5	7.16	1078.8	2.50
1970	982.4	4.77	1075.3	-0.33
1971	1063.4	7.62	1107.5	2.91
1972	1171.1	9.20	1171.1	5.43
1973	1306.3	10.35	1235.0	5.17
1974	1406.9	7.15	1214.0	-1.73
1975	1516.3	7.21	1191.7	-1.87
1976	1691.6	10.36	1264.7	5.77

Source: Survey of Current Business, years 1950-1974 (43:6-9) and years 1975-1976 (44:9).

APPENDIX I

COMPUTER FLOW DIAGRAM


Start
Read Present Value Factors
1
Initialize All Variables. Increase GNP Growth.
GNP Growth
>6%
2
≤6%
3
Year
>1990
1
Calculate GNP, Airline Markets, No. Aircraft Required.
Sum No. of Cargo Capable Aircraft
4
4
Cargo Cap. Acft
<100
5
≥100
1st Year 100 Met
No
6
Yes
Calculate Actual No. 747 Acft. and Costs.
7
6
Calculate Actual No. 747 Acft. and Costs.
7
2
Stop
5
Calculate Actual No. 747 Acft. and Costs
7
Calculate Present Value and Sum Costs-Recoupment
Calculate Amount Flown and Residual Markets.
Write Yr's Results to Output Files
Adjust Variables for Next Year Calculations
3

APPENDIX J

WEIGHT AND VOLUME CHARACTERISTICS
FOR SELECTED AIRCRAFT

Weight and Volume Characteristics for Selected Aircraft

Operating Characteristic	Aircraft Type					
	Long Range Wide-Body			Short/Medium Range		
				Wide-Body		Narrow-Body
	B-747-200B	B-747-200C	B-747-200F	L-1011-1	A-300B4	B-727-200
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Maximum Payload (lbs)	160,700	235,100 (cargo config)	253,000	84,225	75,377	41,000
Range with Maximum Payload (miles)	4,836	2,900	2,900	2,878	1,500	1,845
Passenger Seating:						
Mixed Class	385	385	n/a	256	237	120
All Economy	423	423	n/a	variable	281	163
Maximum High Density	500	500	n/a	400	331	189
Main Deck Cargo (cu ft)	n/a	17,640	17,640	n/a	n/a	n/a
Total Lower Hold Cargo/ Baggage (cu ft)	6,190	5,990	5,990	3,228	4,869	1,485
Forward and Rear Compartments	5,190	5,190	5,190	2,528	4,304	1,485

Operating Characteristic	Aircraft Type					
	Long Range Wide-Body			Short/Medium Range		
				Wide-Body		Narrow-Body
(1)	B-747-200B (2)	B-747-200C (3)	B-747-200F (4)	L-1011-1 (5)	A-300B4 (6)	B-727-200 (7)
Aft Bulk Cargo Compartment (cu ft)	1,000	800	800	700	565	n/a
Total Volume Capacity (cu ft)	6,190	23,630	23,630	3,228	4,869	1,485

Sources: Columns 2, 3, and 4: (7:4, 19, 26, 39, 45-46). Columns 5, 6, and 7: (67 102-104, 270-272, 348-350).

APPENDIX K

PRESENT VALUE DISCOUNT FACTORS USED FOR 1978 THROUGH 1980

The following present value discount factors were used to provide a basis for comparing program year costs:

10% Discount Factor Table

Program Year	Discount Factor Present Value of $1
1978	0.954
1979	0.867
1980	0.788
1981	0.717
1982	0.652
1983	0.592
1984	0.538
1985	0.489
1986	0.445
1987	0.405
1988	0.368
1989	0.334
1990	0.304

The factors are based on continuous compounding of interest assuming uniform cash flows throughout the one-year period. These factors are equivalent to an arithmetic average of beginning and end of year compound amount factors found in standard present value tables. Ten percent is the DoD-established discount rate.

Source: (76:16).

AD-A047 633   AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC   F/G 1/3
AN ECONOMIC ANALYSIS OF A GOVERNMENT SPONSORED, COMMERCIAL CONV--ETC(U)
SEP 77   R J MORGAN, S L MEAD

UNCLASSIFIED   AFIT-LSSR-21-77B   NL

3 OF 3
ADI
A047633

END
DATE
FILMED
1 -78
DDC

APPENDIX L

OPERATING CHARACTERISTICS,
B-747 AIRCRAFT

Operating Characteristics, Boeing B-747 Aircraft

Operating Characteristic	Model			
	Passenger		Convertible	Freighter
	747-100	747-200B	747-200C (Passenger configured)	747-200F
Maximum Taxi Gross Weight (lb)	713,000	778,000	778,000	778,000
Maximum Brake Release Gross Weight (lb)	710,000	775,000	775,000	775,000
Design Landing Weight	564,000	564,000	630,000	630,000
Zero Fuel Weight	526,500	526,500	590,000	590,000
Operating Empty Weight (lb)	356,900	365,800	377,800	337,000
Structural Payload (lb)	169,600	160,700	212,200	253,000
Fuel Capacity: Gallons (U.S.)	42,710	51,430	51,430	51,430
Pounds (@6.7 lb/gal)	286,157	344,580	344,580	344,580

Sources: (7:41,47; 9:2).

APPENDIX M

OPERATING EMPTY WEIGHT (OEW) COMPUTATION

The following computations were made to derive the cost per ton-mile for each ton of Operating Empty Weight (OEW).

United Airlines

[illegible]r/Year	Block Hours	Cost/Hour	Average Payload	Ratio $\frac{\text{OEW}}{\text{Payload + OEW}}$	Total Ratio Cost
2/76	15,723	2,381	26.4	.85648	32,063,594.99
3/76	17,093	2,489	28.1	.86396	36,756,533.14
4/76	15,325	2,464	26.6	.87028	32,862,300.71
1/77	15,668	2,460	26.2	.87198	33,608,836.14
				Total	135,291,265.00

Qtr/Year	Tons OEW per Trip	No. of Departures	Trip Length	Total OEW Ton-miles
2/76	178.45	3,479	2,082	1,292,562,959
3/76	178.45	3,810	2,098	1,426,418,661
4/76	178.45	3,433	2,064	1,264,445,306
1/77	178.45	3,554	2,036	1,291,254,207
			Total	5,274,681,133

Total Ratiod Cost ÷ Total OEW Ton-miles = Cost/Ton-mile OEW
135,291,265.0 ÷ 5,274,681,133 = .02564918

Trans World Airlines

Qtr/Year	Block Hours	Cost/Hour	Average Payload	Ratio*	Ratio Cost
2/76	10,592	2,805	28.3	.86312	25,643,769.93
3/76	12,019	2,532	28.6	.86187	26,228,493.95
4/76	9,776	2,922	26.5	.87070	24,871,961.35
1/77	9,835	3,395	23.9	.88189	29,446,079.92
				Total	106,190,305.10

Qtr/Year	Tons OEW per Trip	No. of Departures	Trip Length	OEW Ton-miles
2/76	178.45	1,679	3,060	916,829,703.0
3/76	178.45	1,868	3,119	1,039,701,807.0
4/76	178.45	1,618	2,931	846,273,785.1
1/77	178.45	1,652	2,859	864,057,041.4
			Total	3,666,862,337.0

Total Ratiod Cost ÷ Total OEW Ton-miles = Cost/Ton-mile OEW
106,190,305.10 ÷ 3,666,862,337.0 = .02895945

*The ratio is OEW divided by OEW plus average payload.

Aggregate Ratiod Cost $\div$ Aggregate Total OEW Ton-miles

= Aggregate Cost/Ton-mile OEW

$$\frac{135,291,065.0 + 106,190,305.1}{5,274,681,133 + 3,666,862,337.0} = \frac{241,481,570.1}{8,941,543,470.0} = .0270066987$$

APPENDIX N

REGRESSION ANALYSIS COMPUTER PROGRAM

```
1000$$S,P(SL) :,8,16::,16
1005$:IDENT:WP1191,AFIT/SLG  MORGAN AND MEAD  770
1010$:SELECT:SPSS/SPSS
1015RUN NAME:THESIS RUN
1020VARIABLE LIST;GNP,PAXMI,TONMI
1025VAR LABELS;GNP,GROSS NATIONAL PRODUCT/
1030;PAXMI,PASSENGER REVENUE MILES/
1035;TONMI,CARGO REVENUE TON MILES
1040INPUT FORMAT;FIXED(1X,F7.1,1X,F9.1,F7.1)
1045INPUT MEDIUM;CARD
1050N OF CASES;27
1055COMPUTE;LNGNP=LN(GNP)
1060COMPUTE;LNPAX=LN(PAXMI)
1065COMPUTE;LNTON=LN(TONMI)
1070REGRESSION;VARIABLES=LNGNP,LNPAX,LNTON
1075;REGRESSION=LNPAX WITH LNGNP(2) RESID=0/
1080;REGRESSION=LNTON WITH LNGNP(2) RESID=0
1085STATISTICS;ALL
1090READ INPUT DATA
1095$:SELECTA:77871/THREGS,R
1100SCATTERGRAM;LNPAX(8.9,12.5),LNGNP(6.1,7.5)/
1101;LNTON(4.9,9.0),LNGNP(6.1,7.5)
1105OPTIONS;7
1110FINISH
1115$:ENDJOB
```

```
DIMENSION GNP(99),PAX(99),TON(99),X(99),Y(99),Z(99)
CALL ATTACH(10,"THEREGS:",1,0,,)
BX=3.33747
AX=-11.48577
BY=3.72425
AY=-17.45730
DO 50 I=1,27
READ(10,15)LP,GNP(I),PAX(I),TON(I)
 15 FORMAT(I4,F7.1,2X,F9.1,F7.1)
Z(I)=ALOG(GNP(I))
X(I)=ALOG(PAX(I))
Y(I)=ALOG(TON(I))
SUMGNP=SUMGNP+GNP(I)
SUMPAX=SUMPAX+PAX(I)
SUMTON=SUMTON+TON(I)
SUMZ=SUMZ+Z(I)
SUMX=SUMX+X(I)
SUMY=SUMY+Y(I)
 50 CONTINUE
XBAR=SUMX/27
YBAR=SUMY/27
ZBAR=SUMZ/27
PAXBAR=SUMPAX/27
TONBAR=SUMTON/27
GNPBAR=SUMGNP/27
DO 60 I=1,27
XHATL=AX+BX*Z(I)
YHATL=AY+BY*Z(I)
RESDXL=X(I)-XHATL
RESDYL=Y(I)-YHATL
SSERXL=SSERXL+RESDXL**2
SSERYL=SSERYL+RESDYL**2
SSTOXL=SSTOXL+(X(I)-XBAR)**2
SSTOYL=SSTOYL+(Y(I)-YBAR)**2
XHAT=EXP(XHATL)
YHAT=EXP(YHATL)
RESIDX=PAX(I)-XHAT
RESIDY=TON(I)-YHAT
SSERX=SSERX+RESIDX**2
SSERY=SSERY+RESIDY**2
SSTOX=SSTOX+(PAX(I)-PAXBAR)**2
SSTOY=SSTOY+(TON(I)-TONBAR)**2
 60 CONTINUE
R2LNX=(SSTOXL-SSERXL)/SSTOXL
R2LNY=(SSTOYL-SSERYL)/SSTOYL
```

```
550 FMSEXL=SSERXL/25
560 FMSEYL=SSERYL/25
570 FLNX=(SSTOXL-SSERXL)/FMSEXL
580 FLNY=(SSTOYL-SSERYL)/FMSEYL
590 RSQX=(SSTOX-SSERX)/SSTOX
600 RSQY=(SSTOY-SSERY)/SSTOY
610 FMSEXR=SSERX/25
620 FMSEYR=SSERY/25
630 FX=(SSTOX-SSERX)/FMSEXR
640 FY=(SSTOY-SSERY)/FMSEYR
650 WRITE(6,20)R2LNX,RSQX,FMSEXL,FMSEXR,FLNX,FX,AX,BX
660 WRITE(6,25)R2LNY,RSQY,FMSEYL,FMSEYR,FLNY,FY,AY,BY
670  20 FORMAT(////,10X,"**********RESULTS**********",//,
680&15X,"*****PAXMI*****",//,3X,"LOG R2",
690&F10.7,3X,"REG R2=",F10.7,//,
700&3X,"LOG MSE=",F9.2,3X,"REG MSE=",F15.2,//,
710&3X,"LOG F=",F11.2,3X,"REG F=",F11.2,//,
720&3X,"LOG XHAT=",F9.5,"+LOG GNP*",F8.5)
730  25 FORMAT(15X,"*****TONMI*****",//,
740&3X,"LOG R2=",F10.7,3X,"REG R2=",F10.7,//,
750&3X,"LOG MSE=",F9.2,3X,"REG MSE=",F15.2,//,
760&3X,"LOG F=",F11.2,3X,"REG F=",F11.2,//,
770&3X,"LOG YHAT=",F9.5,"+LOG GNP*",F8.5)
780 STOP;END
```

APPENDIX O

REGRESSION HYPOTHESIS TESTS AND REGRESSION RESULTS

REGRESSION HYPOTHESIS TESTS

Paxmi*

1. B-test:

H_o:B=0 $(\widehat{\ln Paxmi} = \overline{\ln Paxmi})$

H_a:B≠0 $(\overline{\ln Paxmi} \neq \widehat{\ln Paxmi} = a+b\ (\ln GNP))$

$b_{computed} = 3.33747$
(n = 27)

$b_{crit.\ \alpha/2} = (S_b)\ (t_{crit.\ \alpha/2,n-2})$

$b_{crit.\ \alpha/2 = 0.0005} = (0.07678)\ (3.725) = 0.2860$

$b_{computed} > b_{crit.}$ ∴ Reject H_o and assume B is significant from zero.

2. Correlation Tests:

H_o: $\rho_{(\ln Paxmi \bullet \ln GNP)} = 0$

H_a: $\rho_{(\ln Paxmi \bullet \ln GNP)} \neq 0$

$$t_o = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} = \frac{0.99345\sqrt{27-2}}{\sqrt{1-0.98694}} = 43.465$$

$t_{crit.} = 3.725$
n-2 = 25
$\alpha/2 = 0.0005$

$t_o > t_{crit.}$ ∴ Reject H_o and assume ρ is significant from zero.

*Passenger Revenue Miles

TONMI*

1. B-test:

H_o:B=0 $\quad (\widehat{\text{ln Tonmi}} = \overline{\text{ln Tonmi}})$

H_a:B≠0 $\quad (\overline{\text{ln Tonmi}} \neq \widehat{\text{ln Tonmi}} = a+b\ (\ln GNP))$

$b_{computed} = 3.30561$
(n=27)

$b_{crit} = (S_b)(t_{crit\ \alpha/2,n-2})$
$(\alpha/2)$

$b_{crit} = (0.10003)\ (3.727) = 0.3728$
$\alpha/2=0.0005$

$b_{computed} > b_{crit}$ ∴ Reject H_o and assume B is significant from zero.

2. Correlation Tests:

H_o: $\rho_{(\ln \text{Tonmi} \bullet \ln GNP)} = 0$

H_a: $\rho_{(\ln \text{Tonmi} \bullet \ln GNP)} \neq 0$

$$t_o = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} = \frac{0.99110\sqrt{27-2}}{\sqrt{1-0.98228}} = 37.2268$$

$t_{crit} = 3.725$
n-2 = 25
$\alpha/2 = 0.0005$

$t_o > t_{crit}$ ∴ Reject H_o and assume ρ is significant from zero.

*Cargo Ton-miles

REGRESSION RESULTS
(1950 thru 1976 Data)

	Mean	Std. Dev.
ln GNP	6.7402	0.2711
ln Paxmi	11.0093	0.9108
ln Tonmi	7.6446	1.0188

Paxmi vs GNP

$$\ln \text{Paxmi} = -11.48577 + 3.33747 (\ln \text{GNP})$$

or

$$\text{Paxmi} = (1.02753 \times 10^{-5}) (\text{GNP})^{3.33747}$$

Statistic	Log Value	Reg. Value
r^2	0.98694	0.96813
F	1889.63	759.41
Std. Error	0.10614	3812.65

Durbin-Watson Test = 0.44408, S_b = 0.07678

Tonmi vs GNP

$$\ln \text{Tonmi} = -17.45739 + 3.72425 (\ln \text{GNP}) \quad \text{or}$$

$$\text{Tonmi} = (2.62 \times 10^{-8} (\text{GNP})^{3.72425}$$

Statistic	Log Value	Reg. Value
r^2	0.98228	0.91143
F	1386.18	257.27
Std. Error	0.1383	786.69

Durbin-Watson Test = 0.44917 S_b = 0.10003

APPENDIX P

MARKET FORECAST COMPUTER PROGRAM

```
C   PHASEIII PROGRAM
C SEEP--STANDARD ERROR OF THE MEAN EST. FOR PAXMI
C SEET--STANDARD ERROR OF THE MEAN EST. FOR TONMI
C BV--BIASED VARIENCE
C SEEGP--STD. ERROR OF THE EST. FOR A GIVEN GNP-PAXMI
C SEEGT--STD. ERROR OF THE EST. FOR A GIVEN GNP-TONMI
C T-- T-VALUE FOR 95% CONFIDENCE INTERVAL
C CIP--CONVIDENCE INTERVAL FOR PAXMI
C CIT--CONFIDENCE INTERVAL FOR TONMI
C GNPM--THE MEAN OF GNP
 CALL ATTACH(10,"PHASE3OP;",3,0,,)
 DELTAGNP=0.005
 BV=1.98437
 T=2.06
 GNPM=6.7402
 SEEP=0.09960
 SEET=0.13828
 5 IF(DELTAGNP.GT.0.06) GO TO 99
 WRITE(10,20) DELTAGNP
 GNP=1264.7
 LN=1976
 WRITE(10,10)
 8 IF(LN.EQ.1991) GO TO 999
 ALNGNP=ALOG(GNP)
 SEEGP=SEEP*(1+1/27+(ALNGNP-GNPM)**2/BV)
 CIP=T*SEEGP
 ALNPAXMI=-11.48577+3.33747*ALNGNP
 ALPAXMIU=ALNPAXMI+CIP
 ALPAXMIL=ALNPAXMI-CIP
 PAXMI=EXP(ALNPAXMI)
 PAXMIU=EXP(ALPAXMIU)
 PAXMIL=EXP(@LPAXMIL)
 ALNTONMI=-17.45739+3.72425*ALNGNP
 SEEGT=SEET*(1+1/26+(ALNGNP-GNPM)**2/BV)
 CIT=T*SEEGT
 ALTONMIU=ALNTONMI+CIT
 ALTONMIL=ALNTONMI-CIT
 TONMI=EXP(ALNTONMI)
 TONMIU=EXP(ALTONMIU)
 TONMIL=EXP(ALTONMIL)
 WRITE(10,15) LN,PAXMIU,PAXMI,PAXMIL,TONMIU,TONMI,TONMIL
 GNP=GNP+GNP*DELTAGNP
 LN=LN+1
 GO TO 8
 999 DELTAGNP=DELTAGNP+0.005
```

```
 GO TO 5
 10 FORMAT(/,20X,"PASSENGER",25X,"CARGO",/,
&18X,"REVENUE MILES",18X,"REVENUE MILES",/,
&2X,"YEAR",2(6X,"UPPER",6X,"MEAN",6X,"LOWER"))
 15 FORMAT(2X,I4,3(2X,F10.1),1X,
&F8.1,2X,F8.1,2X,F8.1)
 20 FORMAT(//,20X,"ANNUAL % CHANGE IN GNP(/100)=",1X,F6.3)
 99 REWIND 10
 STOP;END
```

APPENDIX Q

MAIN COMPUTER PROGRAM FOR A 30-50-20 MARKET SPLIT

```
0010C  CONVERTIBLE ECONOMIC FORECAST PROGRAM
0020C FOR SITUATION C RUN AS IS
0030C      FOR SITUATION B CHANGE THE FOLLOWING LINES TO READ
0040C      00265 PWB=0.XX
0050C      00270 PNB=1.0-0.XX
0060C      00275 PMR=0.00
0070C      WHERE 0.XX IS YOUR DESIRED PERCENT LONG RANGE WB
0080C           FOR SITUATION A CHANGE THEM TO READ
0090C           00265 PWB=0.XX ; 00270 PNB=0.0 ; 00275 PMR=0.0
0100C  LIST OF VARIABLES
0110C      *****ABREVATIONS*****
0120C  WB=LONG RANGE WIDE BODY AIRCRAFT (BOEING 747)
0130C  NB=MEDIUM/SHORT RANGE NARROW BODY AIRCRAFT (BOEING 727)
0140C  MR=MEDIUM/SHORT RANGE WIDE BODY AIRCRAFT(LOCHEED 1011)
0150C      *****LIST OF VARIABLES*****
0160C PWB--PRECENT OF MARKET FLOWN BY WB
0170C PNB--PERCENT OF MARKET FLOWN BY NB
0180C PMR--PERCENT OF MARKET FLOWN BY MR
0190C B747C--WB CONVERTIBLE AIRCRAFT
0200C B747A--TOTAL NUMBER OF WB PASSENGER AIRCRAFT FLYING
0210C B747F--TOTAL NUMBER OF WB FREIGHTER AIRCRAFT FLYING
0220C B727A--TOTAL NUMBER OF NB FLYING
0230C L1011--TOTAL NUMBER OF MR FLYING
0240C RB747A--REQUIRED NO. OF PASSENGER WB FOR THAT YEAR
0250C RB747F--REQUIRED NO. OF FREIGHTER WB FOR THAT YEAR
0260C RB727A--REQUIRED NUMBER OF NB FOR THAT YEAR
0270C RL1011--REQUIRED NUMBER OF MR FOR THAT YEAR
0280C CB747A--CURRENT NO. OF PASSENGER WB FLYING
0290C CB747F--CURRENT NO. OF FREIGHTER WB FLYING
0300C PVF--PRESENT VALUE FACTOR
0310C DELTAGNP--AVERAGE ANNUAL CHANGE IN GNP
0320C LN--CURRENT YEAR
0330C RECOUP--RECOUPMENT PAYMENT
0340C TRECP---TOTAL AMOUNT OF RECOUPMENT
0350C RP--ANNUAL RECOUPMENT PER FREIGHTER WB EQUALIENT
0355C      (MILLION $)
0360C ATCOST--TOTAL ANNUAL BUDGET COST
0370C TCOST--TOTAL COST OF PROGRAM
0380C CCOST---COST OF CONVERSION
0390C CP--CONVERSION COST PER WB CONVERTIBLE (MILLION $)
0400C SCOST---SUBSIDY COST
0410C OC--ANNUAL COST PER WB CONVERTIBLE FLOWN (MILLION $)
0420C COSOFWT--
0430C CAPC--PRESENT VALUE OF TOTAL ANNUAL BUDGET COST
0440C CAPR--PRESENT VALUE OF ANNUAL RECOUPMENT
```

```
C CPVC--TOTAL PRESENT VALUE OF PROGRAM COSTS
C CPVR--TOTAL PRESENT VALUE OF PROGRAM RECOUPMENT
C PCC--MILLION LOWER HOLD CARGO TONMI / B747A YEAR
C NSPA--NUMBER OF SEATS PER AIRCRAFT
C NSPNBA--NUMBER SEATS PER NB
C NSPMRA--NUMBER SEATS PER MR
C APLF--AVERAGE PASSENGER LOAD FACTOR
C AAS--AVERAGE AIRBORNE SPEED
C AASNB--AVERAGE AIR SPEED OF NB
C AASMR--AVERAGE AIR SPEED OF MR
C AUF--AVERAGE ULTILIZATION FACTOR
C AUFNB--AVERAGE ULTILIZATION FACTOR NB
C AUFMR--AVERAGE ULTILIZATION FACTOR MR
C AUFF--AVERAGE ULTILIZATION FACTOR FOR B747F
C TVLLC--TOTAL VOLUME OF LOWER LOBE COMPARTMENTS
C TVLLCNB--TOTAL VOLUME OF LOWER LOBE COMPARTMENTS OF NB
C TVLLCMR--TOTAL VOLUME OF LOWER LOBE COMPARTMENTS OF MR
C CFPP--CUBIC FEET PER PASSENGER ALLOCATED FOR BAGGAGE
C       IN LOWER LOBE
C ALHEF--AVERAGE LOWER LOBE ENPLANEMENT FACTOR FOR CARGO
C ALHEFMR--AVERAGE LOWER LOBE ENPLANEMENT FACTOR MR
C ALHEFNB--AVERAGE LOWER LOBE ENPLANEMENT FACTOR NB
C CC--CARGO CAPACITY OF B747C OR B747F IN CUBIC FEET
C DF--DENSITY FACTOR FOR CARGO DENSITY IN POUNDS/CUBIC FT
C ACLF--AVERAGE CARGO LOAD FACTOR FOR B747C OR B747F
C PC--MILLION PASSENGER MILES PER B747A PER YEAR
C PCNB--MILLION PASSENGER MILES PER NB
C PCMR--MILLION PASSENGER MILES PER MR
C FC--MILLION CARGO TON MILES PER B747C OR B747F PER YEAR
C PCC--MILLION CARGO TON MILES FLOWN PER PASSENGER WB
C PCCNB--MILLION CARGO TON MILES PER NB
C PCCMR--MILLION CARGO TON MILES PER MR
C SEATMI--PAST YEAR PASSENGER MARKET
C ATONMI--PAST YEAR CARGO TON MILE MARKET
C TONMI1--TON MILE MARKET FORECASTED FOR 1977
C TONMI--CURRENT YEAR FORECAST FOR CARGO TON MILES
C PAXMI--CURRENT YEAR FORECAST FOR PASSENGER MILES
C NACFT--TOTAL NUMBER OF CARGO CAPIABLE WB
      DIMENSION PVF(99)
      INTEGER B747A,B747F,B747C,RB747A,RB747F,RB747C,
     &CB747A,CB747C,CB747F,RB727A,B727A,RL1011
C     CALL AND ATTACH INPUT AND OUTPUT FILES
      CALL ATTACH(13,"ACFTOP3;",3,0,,)
      CALL ATTACH(14,"COSTOP3;",3,0,,)
      CALL ATTACH(11,"INTFAC;",1,0,,)
      DO 1 N=1,25
C     READ PRESENT VALUE FACTORS
```

```
      READ(11,7001,END=2)DUM,PVF(I)
 7001 FORMAT(V)
    1 CONTINUE
C     WRITE OUTPUT FILE HEADINGS
      WRITE(13,7003)
      WRITE(14,7004)
C     START OF GNP LOOP
    2 DELTAGNP=0.0
    3 IF(DELTAGNP.GT.0.06)GO TO 9
      DELTAGNP=DELTAGNP+0.005
C     LABEL THE AVERAGE ANNUAL CHANGE IN GNP
      WRITE(13,7002)DELTAGNP
      WRITE(14,7002)DELTAGNP
 7002 FORMAT(20X,"DELTAGNP=",F6.3)
C     BREAK-OUT PERCENTAGES
      PWR=0.10
      PNR=0.50
      PMR=0.40
C     AIRCRAFT CAPIBILITY PARAMETERS
      NSPA=423
      NSPNBA=130
      NSPMBA=250
      APLF=0.6
      AAS=505.31
      AASNB=421.5
      AASMB=476.03
      AUF=9.1
      AUFNB=7.5
      AUFMB=7.5
      AUFF=11.5
      TVLLC=6190.0
      TVLLCNB=1485.0
      TVLLCMB=4869.0
      CFPP=5.0
      ALHEF=0.35
      ALHEFNB=0.20
      ALHEFMB=0.25
      CC=23630.0
C     1977 PROGRAM COSTS
      RP=0.23895782
      CP=5.6788
      COSOEWT=0.0270066987
      OC=6.0*AAS*AUF*365*COSOEWT/1000000
C     ADJUSTMENT OF OC TO JULY 1977 FOR 6 PCT INFLATION
      OC=OC*1.015
      UF=9.8
      ACLF=0.7
```

```
C     CALCULATION OF AIRCRAFT CAPABILITIES
       PC=NSPA*APLF*AAS*AUF*365/1000000
       PCNB=NSPNBA*APLF*AASNB*AUFNB*365/1000000
       PCMR=NSPMRA*APLF*AASMR*AUFMR*365/1000000
       PCC=(TVLLC-NSPA*APLF*CFPP)*DF*AAS*ALHEF*AUF*365/
         &2000000000
       PCCNB=(TVLLCNB-NSPNBA*APLF*CFPP)*DF*AASNB*AUFNB*
      &ALHEFNB*365/2000000000
       PCCMR=(TVLLCMR-NSPMRA*APLF*CFPP)*DF*AASMR*ALHEFMR*
      &AUFMR*365/2000000000
       FC=CC*DF*ACLF*AAS*AUFF*365/2000000000
C     CALCULATION OF 1977 FORECAST VALUES OF THE MARKET
       GNP=1264.7+1264.7*DELTAGNP
       ALNGNP=ALOG(GNP)
       ALNPAXMI=-11.48577+3.33747*ALNGNP
       SEATMI=EXP(ALNPAXMI)
       ALNTONMI=-17.45739+3.72425*ALNGNP
       ATONMI=EXP(ALNTONMI)
C     INITIALIZING VARIABLES
       TONMI1=ATONMI
       CB747A=0
       CB747F=0
       CB747C=0
       RB747A=0
       RB747C=0
       RB747F=0
       B727A=0
       RB727A=0
       RL1011=0
       L1011=0
       B747A=0
       B747C=0
       B747F=0
       B747C1=0.0
       NACFT=0.0
       TRECP=0.0
       CPVC=0.0
       CPVR=0.0
       TCOST=0.0
       LN=1977
       I=0
       N=0
        K=0
       GO TO 8
     4 IF(LN.EQ.1991)GO TO 3
       N=N+1
C     COSTS INFLATED BY ONE YEAR
```

```
      RP=RP*1.06
      OC=OC*1.06
      CP=CP*1.06
C     MARKET FORECAST AND CONVERSION CALCULATIONS
      ALNGNP=ALOG(GNP)
      ALNPAXMI=-11.48577+3.33747*ALNGNP
      PAXMI=EXP(ALNPAXMI)
      ALNTONMI=-17.45739+3.72425*ALNGNP
      TONMI=EXP(ALNTONMI)
      RB747A=(PAXMI-SEATMI)*PWB/PC
      RB727A=(PAXMI-SEATMI)*PNB/PCNB
      RL1011=(PAXMI-SEATMI)*PMR/PCMR
      IF(RB747A.LT.0)RB747A=0
      IF(RB727A.LT.0)RB727A=0
      IF(RL1011.LT.0)RL1011=0
      RB747F=(TONMI-ATONMI-RB747A*PCC-RB727A*PCCNB-
     &RL1011*PCCMR)/FC
      IF(RB747F.LT.0)RB747F=0
      CB747C=CB747C+RB747A
      NACFT=CB747C+RB747F+CB747F
C     LIMITING NUMBER OF CARGO CAPIBLE AIRCRAFT TO 100
C     COST CALCULATIONS ARE BASED ON THE NUMBER OF
C           CARGO CAPIBLE AIRCRAFT
      IF(NACFT.LT.100)GO TO 6
      I=I+1
      IF(I.GT.1)GO TO 5
      B747C1=CB747C-NACFT+100
       IF(B747C1.LT.B747C) B747C1=B747C
      CCOST=(B747C1-B747C)*CP
      B747A=CB747C-B747C1
      CB747F=CB747F+RB747F
      B747C=B747C1
      SCOST=B747C*OC
      GO TO 7
    5 B747C=B747C1
      B747F=B747F+RB747F
       IF(B747F.GT.B747C) GO TO 10
      SCOST=(B747C-B747F)*OC
      RECOUP=B747F*RP
      CCOST=0.0
      B747A=B747A+RB747A+RB747F
      GO TO 7
   10 CB747F=CB747F+(B747F-B747C)
       K=K+1
       DIFF=RB747F-(B747F-B747C)
       IF(K.GT.1) DIFF=0.0
       B747F=B747C
```

```
      RECOUP=B747C*RP
      SCOST=0.0
      CCOST=0.0
      B747A=B747A+RB747A+DIFF
      GO TO 7
    6 B747C=CB747C
      SCOST=B747C*OC
      CB747F=CB747F+RB747F
      CCOST=RB747A*CP
      RECOUP=0.0
    7 IF(SCOST.LT.0.0)SCOST=0.0
      TCOST=TCOST+CCOST+SCOST
      TACOST=CCOST+SCOST
      B727A=B727A+RB727A
      L1011=L1011+RL1011
      TRECP=TRECP+RECOUP
C     CALCULATION OF CARGO MILES FLOWN BY AIRCRAFT TYPES
      CONLH=(B747C-B747F)*PCC/1000
      PAXLH=B747A*PCC/1000
      PAXNBLH=B727A*PCCNB/1000
      PAXWBLH=L1011*PCCWB/1000
      CONCAP=B747C*FC/1000
      CONUSED=B747F*FC/1000
      FRTMI=CB747F*FC/1000
      CARGO=(TONMI-TONMI1)/1000
      RESID=CARGO-CONLH-PAXLH-FRTMI-PAXNBLH-PAXWBLH-
     &CONUSED
C     PRESENT VALUE CALCULATION OF COSTS
      CAPC=TACOST*PVF(N)
      CAPR=RECOUP*PVF(N)
      CPVC=CPVC+CAPC
      CPVR=CPVR+CAPR
C     OUTPUT OF DATA TO FILES
      WRITE(13,7005)LN,B727A,L1011,B747A,B747C,CB747F,
     &  CARGO,CONLH,PAXLH,PAXNBLH,PAXWBLH,FRTMI,
     &  RESID,CONCAP,CONUSED,B747F
      WRITE(14,7006)LN,B747C,CP,CCOST,SCOST,TACOST,
     &  CPVC,RECOUP,CPVR
C     ADJUST VARIABLES FOR FOLLOWING YEAR
      SEATMI=PAXMI
      ATONMI=TONMI-RESID*1000.0
    8 GNP=GNP+GNP*DELTAGNP
      CB747A=CB747A+RB747A
      LN=LN+1
C     REPEAT LOOP FOR FOLLOWING YEAR
      GO TO 4
C     FORMAT STATEMENTS OF OUTPUT FILES
```

```
 7003 FORMAT(91X,"ANNUAL",2X,"ANNUAL",/,
     &14X,"CUMULATIVE",17X,"TONMI",2X,"ENCNV",2X,
     &"B747C",2X,"B727",2X,"L1011",
     &2X,"EPIR",3X,"RESIR",2X,"TONMI",3X,"TONMI",/,
     &1X,"YEAR",2X,"B727",2X,"L1011",2X,"B747B",2X,
     &"B747C",2X,"B747F",2X,"FCAST"
     &6(2X,"TONMI"),3X,"CAP",5X,"USED",2X,"CON-ERT")
 7004 FORMAT(20X,"ANNUAL",2X,"ANNUAL",2X,"TOTAL",
     &5X,"CUM",14X,"CUM",/,8X,"CUM",3X,"CONV",2X,
     &"INVEST",3X,"OPS",4X,"ANNUAL",2X,"PRESENT",
     &2X,"ANNUAL",2X,"PRESENT",/,2X,"YEAR",2X,"ACFT",
     &2X,"COST",3(2X,"BUDGET"),3X,"COST",4X,"RECOUP",
     &2X,"RECOUP")
 7005 FORMAT(5(1X,I4,2X),1X,I4,1X,7(F6.3,1X),1X,F6.3,
     &2X,F6.3,2X,I4)
 7006 FORMAT(2X,I4,2X,I4,1X,F6.1,F7.1,1X,
     &F7.1,1X,F7.1,1X,F8.1,3X,F7.1,1X,F8.1)
C     REWIND OUTPUT FILES-----NECESSARY TO PREVENT ERROR
    9 REWIND 13
      REWIND 14
      STOP
      END
```

APPENDIX R

SUMMARY OF TIME INTERVALS FOR SITUATIONS A, B, C-1, AND C-2

Average Annual GNP Growth (%)	Year in which 100 Cargo Capable Aircraft Enter Fleet with Government/Non-government Program for Situation A and B					
	Annual Percentage Passenger Revenue Miles Flown by B747B/B-727/L-1011 Aircraft					
	# Aircraft in 1990					
	10/90/0	20/80/0	30/70/0	40/60/0	50/50/0	100/0/0
0.5	(18)/(10)	(30)/(9)	(33)/(9)	(55)/(8)	(67)/(7)	1988/(4)
1.0	(47)/(23)	(76)/(22)	1990/(20)	1988/(19)	1986/(17)	1982/(10)
1.5	(87)/(41)	1988/(38)	1986/(36)	1984/(33)	1983/(31)	1981/(18)
2.0	1988/(65)	1985/(60)	1983/(56)	1982/(52)	1982/(48)	1980/(29)
2.5	1986/(93)	1983/(88)	1982/(83)	1981/(79)	1981/(72)	1979/(44)
3.0	1984/1989	1982/1989	1981/1990	1981/1990	1980/1990	1979/(65)
3.5	1983/1987	1982/1987	1981/1988	1980/1988	1980/1988	1979/(92)
4.0	1983/1986	1981/1986	1980/1986	1980/1987	1979/1987	1979/1989
4.5	1982/1985	1980/1985	1980/1985	1980/1986	1979/1986	1978/1988
5.0	1981/1984	1980/1984	1980/1984	1979/1985	1979/1984	1978/1987
5.5	1981/1983	1981/1984	1979/1984	1979/1984	1979/1984	1978/1986
6.0	1981/1983	1980/1983	1979/1983	1979/1983	1979/1984	1978/1985
6.5	1980/1982	1980/1983	1979/1983	1979/1983	1979/1983	1978/1984

Average Annual GNP Growth (%)	Year in which 100 Cargo Capable Aircraft Enter Fleet with Government/Non-government Program for Situation C-1				
	Annual Percentage Passenger Revenue Miles Flown by B-747B/B-727/L-1011 Aircraft				
	# Aircraft in 1990				
	10/45/45	20/40/40	30/35/35	40/30/30	50/25/25
0.5	(15)/(7)	(28)/(7)	(41)/(7)	(53)/(6)	(66)/(6)
1.0	(41)/(17)	(70)/(16)	(99)/(15)	1988/(15)	1986/(14)
1.5	(75)/(29)	1988/(28)	1986/(27)	1984/(26)	1983/(25)
2.0	1989/(46)	1986/(54)	1984/(43)	1983/(41)	1982/(39)
2.5	1986/(69)	1984/(66)	1982/(63)	1981/(60)	1981/(58)
3.0	1985/(98)	1983/(94)	1982/(91)	1981/(87)	1980/(83)
3.5	1984/1989	1982/1989	1981/1989	1980/1989	1980/1990
4.0	1984/1987	1981/1987	1980/1988	1980/1988	1979/1988
4.5	1982/1986	1981/1986	1980/1986	1980/1987	1979/1987
5.0	1982/1985	1980/1985	1980/1985	1979/1986	1979/1986
5.5	1981/1984	1980/1985	1980/1985	1979/1985	1979/1985
6.0	1981/1984	1980/1984	1979/1984	1979/1984	1979/1984
6.5	1981/1984	1980/1983	1979/1983	1979/1984	1979/1984

Average Annual GNP Growth (%)	Year in which 100 Cargo Capable Aircraft Enter Fleet with Government/Non-government Program for Situation C-2			
	Annual Percentage Passenger Revenue Miles Flown by B-747B/B-727/L-1011 Aircraft			
	# Aircraft in 1990			
	10/50/40	20/50/30	30/50/20	40/50/10
0.5	(16)/(18)	(39)/(8)	(42)/(8)	(55)/(8)
1.0	(41)/(17)	(72)/(18)	1990/(18)	1988/(18)
1.5	(77)/(31)	1988/(31)	1986/(31)	1984/(31)
2.0	1989/(48)	1985/(48)	1984/(48)	1982/(48)
2.5	1987/(71)	1984/(51)	1982/(72)	1981/(72)
3.0	1985/1990	1983/1990	1981/1990	1981/1990
3.5	1984/1989	1982/1988	1981/1988	1980/1988
4.0	1983/1987	1981/1987	1980/1987	1980/1987
4.5	1982/1986	1981/1986	1980/1986	1980/1986
5.0	1982/1985	1980/1985	1980/1985	1979/1985
5.5	1981/1984	1980/1984	1980/1985	1979 1984
6.0	1981/1984	1980/1984	1979/1984	1979/1984
6.5	1981/1983	1980/1983	1979/1983	1979/1983

APPENDIX S

SUMMARY OF DISCOUNTED PROGRAM COSTS FOR SITUATIONS A, B, C-1, AND C-2

Average Annual GNP Growth (%)	Situation A and B Discounted Program Costs (million $)					
	Percent Annual Passenger Revenue Miles Flown by B-747B/B-727 Aircraft					
	10/90	20/80	30/70	40/60	50/50	100/0
0.5	(40.7)	(120.0)	(199.4)	(278.7)	(358.1)	637.9
1.0	(141.8)	(318.0)	480.1	552.0	607.0	742.2
1.5	(265.7)	449.9	550.3	613.7	656.4	768.4
2.0	319.1	482.8	574.6	631.0	660.0	774.6
2.5	339.0	498.0	570.8	630.0	655.1	777.8
3.0	337.9	484.7	563.4	593.7	650.2	759.4
3.5	331.4	459.7	527.2	595.7	618.4	735.6
4.0	347.1	456.2	538.9	568.3	629.2	711.9
4.5	307.9	451.5	515.1	587.3	605.2	714.2
5.0	331.3	457.7	488.4	568.9	585.0	698.4
5.5	292.2	426.4	528.6	550.2	566.2	679.1
6.0	325.0	403.7	511.7	526.8	549.2	667.7
6.5	326.5	447.9	490.0	512.2	534.6	651.1

( ) indicates Program Goal not met.

Average Annual GNP Growth (%)	Situation C-1 Discounted Program Costs (million $)				
	Percent Annual Passenger Revenue Miles Flown by B-747B/B-727/L-1011				
	10/45/45	20/40/40	30/35/35	40/30/30	50/25/25
0.5	(40.7)	(120.0)	(199.4)	(278.7)	(358.1)
1.0	(141.8)	(318.0)	(495.6)	565.9	618.0
1.5	(265.7)	486.7	573.0	634.6	672.4
2.0	357.3	524.5	596.6	654.8	685.2
2.5	395.8	527.8	616.1	664.4	686.6
3.0	381.7	519.0	617.1	637.1	681.9
3.5	381.0	513.8	580.2	632.7	653.1
4.0	369.1	517.7	586.2	608.6	658.1
4.5	381.6	490.3	565.8	597.6	637.9
5.0	368.9	518.4	536.7	607.4	615.7
5.5	383.5	490.3	563.5	586.8	602.0
6.0	345.4	471.0	554.1	569.1	583.7
6.5	364.3	452.8	536.5	551.8	568.3

Average Annual GNP Growth (%)	Situation C-2 Discounted Program Costs (million $)			
	Percent Annual Passenger Revenue Miles Flown by B-747B/B-727/L-1011			
	10/50/40	20/50/30	30/50/20	40/50/10
0.5	(40.7)	(120.0)	(199.4)	(278.7)
1.0	(141.8)	(318.0)	487.8	556.5
1.5	(265.7)	477.4	561.8	620.5
2.0	353.0	519.5	583.1	640.0
2.5	390.3	513.8	597.0	640.8
3.0	374.3	514.8	592.4	610.9
3.5	380.2	491.7	559.3	606.9
4.0	357.4	501.4	566.1	579.5
4.5	374.7	469.7	541.3	590.0
5.0	368.2	502.5	513.6	579.7
5.5	371.5	475.6	558.7	559.9
6.0	333.2	450.1	535.7	542.3
6.5	363.8	451.3	519.9	527.0

APPENDIX T

SUMMARY OF REIMBURSEMENTS FOR
SITUATIONS A, B, C-1, AND C-2

Average Annual GNP Growth (%)	Situation A and B Discounted Program Recoupment (million $)					
	Percent Passenger Revenue Miles Flown by B-747B/B-727					
	10/90	20/80	30/70	40/60	50/50	100/0
0.5	0.0	0.0	0.0	0.0	0.0	0.3
1.0	0.0	0.0	0.0	0.9	2.4	4.9
1.5	0.0	1.9	6.0	10.6	12.1	10.4
2.0	3.4	14.3	22.4	25.9	23.9	20.1
2.5	16.1	36.8	41.8	46.4	43.3	35.2
3.0	37.1	58.1	68.1	64.3	71.2	49.1
3.5	49.2	66.5	78.1	89.6	86.5	67.8
4.0	55.1	83.5	100.4	99.8	111.2	86.3
4.5	60.2	88.5	106.3	110.4	120.4	155.9
5.0	76.2	106.8	108.0	128.9	126.7	171.0
5.5	69.9	104.6	132.5	133.0	131.7	180.2
6.0	77.8	101.7	134.6	134.6	135.3	189.6
6.5	91.5	114.3	134.2	135.6	137.1	196.4

Average Annual GNP Growth (%)	Situation C-1 Discounted Program Recoupment (million $)				
	Percent Passenger Revenue Miles Flown by B-747B/B-727/L-1011				
	10/45/45	20/40/40	30/35/35	40/30/30	50/25/25
0.5	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.6	1.9
1.5	0.0	1.4	4.3	8.1	9.5
2.0	0.8	7.4	13.8	17.1	19.9
2.5	7.6	21.4	32.1	35.4	35.0
3.0	24.8	40.2	46.8	51.8	57.0
3.5	39.6	61.1	69.9	77.5	76.4
4.0	52.6	80.5	92.8	91.7	100.4
4.5	67.3	86.3	102.5	101.5	113.4
5.0	68.8	107.7	106.3	123.9	121.4
5.5	85.3	109.6	116.4	129.7	129.1
6.0	79.0	110.3	133.4	133.4	133.7
6.5	85.5	110.1	136.5	136.7	136.3

Average Annual GNP Growth (%)	Situation C-2 Discounted Program Recoupment (million $)			
	Percent Annual Passenger Revenue Miles Flown by B-747B/B-727/L-1011			
	10/50/40	20/50/30	30/50/20	40/50/10
0.5	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.9
1.5	0.0	1.6	5.0	9.9
2.0	0.9	11.7	15.1	24.1
2.5	12.4	23.2	36.8	43.3
3.0	26.3	43.9	62.0	62.0
3.5	40.2	62.5	75.5	86.5
4.0	51.7	82.1	96.8	96.8
4.5	67.5	85.3	103.7	108.0
5.0	69.4	108.1	106.2	126.7
5.5	83.1	108.8	120.6	131.7
6.0	77.0	108.3	135.1	135.3
6.5	85.9	111.4	136.7	136.9

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